MICROCONTROLLER BOARD FOR ROBOT APPLICATIONS

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Bachelor of Mechatronics Engineering

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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering

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ABSTRACT

The purpose of this project is to design and fabricate a microcontroller board suitable for robot applications. The preferred choice of microcontroller chip is the PIC MCU family from Microchip. The board fulfills the requirements of common autonomous mobile robots, such as the line following robots and the "pick and place" robots, whose size ranges from small to medium size. The microcontroller board is an attempt to improve upon the AR40B autonomous robot controller from Cytron Technologies, and comparison will be made against each other. The reason behind using a microcontroller for robot control is that it packs adequate processing speed, program memory, and I/O ports inside a compact and affordable chip. The completed microcontroller board is able to interface easily with external electric/electronic components, such as DC brushed/brushless motor and digital/analog sensors. The microcontroller board has undergone extensive testing to ensure that the finished product will provide a proven and reliable platform upon which robot builders can develop their models rapidly and efficiently, without being hindered by technical problems from the controller board.

ABSTRAK

Tujuan projek ini adalah untuk mereka bentuk dan menghasilkan satu litar pengawal mikro yang sesuai untuk applikasi robot. Jenis microcontroller yang akan dipilih adalah MCU daripada Microchip. Litar pengawal robot mikro ini akan memenuhi keperluan jenis robot seperti robot mengikut garisan di mana saiznya adalah kecil sehingga sederhana. Projek ini bertujuan untuk menambahkan fungsi kepada pegawal mikro robot AR 40B yang dihasilkan oleh Cytron Technology Sdn Bhd, dan perbandingan akan dibuat antara satu sama lain. Tujuan microcontroller dipilih untuk aplikasi ini adalah kerana ia mempunyai kelajuan memproses, isian ingatan, dan kaki masukan/keluaran yang mencukupi. Litar pengawal robot yang dihasilkan boleh disambungkan kepada komponen electric dengan mudahnya, contohnya seperti motor electric DC dan sensor digital/analog. Pengawal robot yang dihasilkan telah melalui ujian yang menyeluruh supaya ia boleh menjadi satu pelantaran untuk memudahkan pembina robot memajukan rekabentuk robot dengan cepat dan cekap tanpa disekat oleh masalah teknikal daripada pengawal mikro.

I dedicate this report to my beloved father and mother

ACKNOWLEDGEMENT

I would like to express my gratitude to my supervisor, Mr Ahmad Zaki bin Hj Shukor, for his patience in guiding me to find a direction for this project. I would also like to thank all my friends who have helped me in the development of this project.

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

In this project, a robot controller board is designed, built, test and fabricated using PCB method. The robot controller is able to fulfill the needs of common robot such as line follower.

1.2 Problem Statement

The robot controller discussed in this project utilizes a PIC 18F4431 microcontroller as the brain of the system. The microcontroller based controller is very popular among the academic fraternity for used in robotic applications due to its ease of programming, small size factor (versatile for embedded system), wide availability, and adequate processing power.

For the purpose of this project, the AR 40B robot controller produced by Cytron Technology Sdn. Bhd. is chosen to be used as a comparison and benchmark. The AR 40B is chosen for the reason that it is a homegrown product which can be easily afforded and purchased by the locals, especially university students who often need to acquire a robot controller for their projects on a shoestring budgets. The functions of the AR 40B are more geared towards academic purposes as it is suitable for robots such as autonomous line follower, pick-and-place robots, and obstacles avoidance robots, as described in [1]. These robot types are commonly used as the foundations to teach engineering students the foundations of robotics. The Faculty of

Electrical Engineering in UTeM has also purchased several sets of AR 40B controller for use in the participation ROBOCON competition.

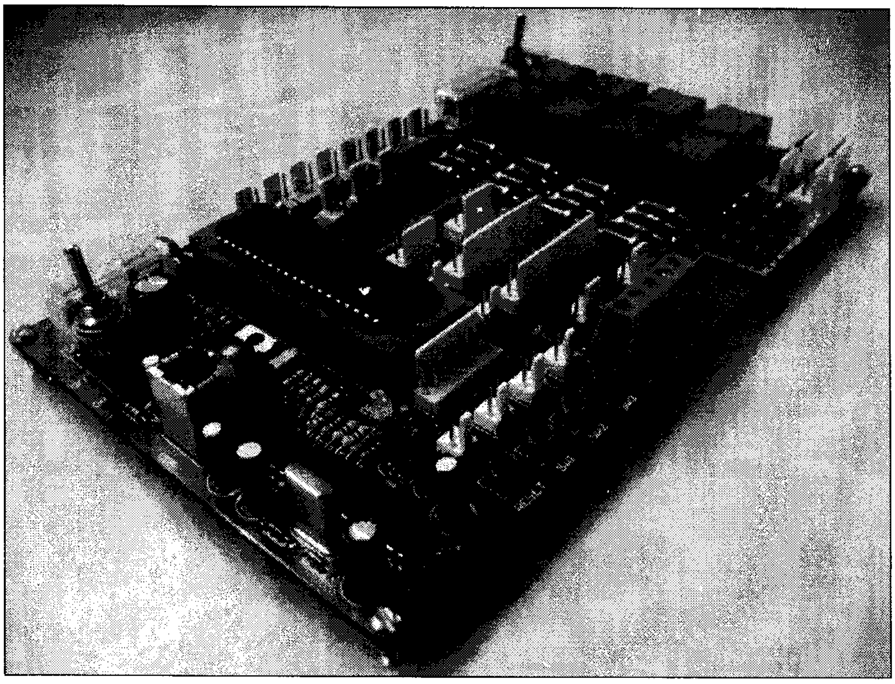

Figure 1.1: The AR 40B robot controller board.

However, several shortcomings have been identified in the AR 40B which demand attention for improvements. Function-wise, the AR 40B is only capable of generating 2 channels of Pulse Width Modulation (PWM) to support 2 Brushless DC motor (BLDC). Even though this is adequate for normal situation, there are a number of robot applications which could require the use of 4 independent-PWM supported motor drives, such as the mecanum wheel robot and the omni wheel robot. Furthermore, the robot builder may also choose to have 4 PWM-supported DC motors as drive train to increase the speed and agility of a typical autonomous robot. From the ergonomics perspective, the AR 40B lacks user-friendly features such as the liquid crystal display (LCD) and keypad for instructions inputs. Without the LCD and keypad, the only way for the user to modify the parameters of the program is to connect the microcontroller is to the computer through a usb programmer and re-download the modified software program. Therefore, a lot of time and effort can be saved if the user can change the parameters of the software on the spot. The user will be able to concentrate on modifying the software parameters without having to divert attention to the task of programming the microcontroller. For safety reasons, it is also advisable to substitute on-board relays of the AR 40B to separate the control circuit from the dangerous voltage spikes produce by the relays.

For the reasons stated above, it can be clearly seen that the shortcomings associated with the AR 40B justify this project's initiative to develop an improved version of robot controller in terms of functions, ergonomics, and safety precautions. The improved version will provide a plug-and-play foundation on which robot builder can concentrate on developing their robot without having to spend time on robot controller design considerations.

1.3 Objectives

The ultimate objective of the project is to produce a workable robot controller on printed circuit board (PCB) as the end product. The main target audience of the robot controller is made up of university engineering students who are involved in developing robots for academic purposes. The following table shows a break-up of the main objective:

Table 1.1: The objectives of the project.

Objectives	**Description**
Objective 1: To increase PWM channels.	The robot controller is be able to generate 4 channels of PWM signal to control 4 units of brushless motors (BLDC).
Objective 2: To integrate an LCD display and a keypad.	A liquid crystal display (LCD) for information display and a keypad for instructions inputs is be integrated into the robot controller design.
Objective 3: To substitute relays with optocouplers.	The 8 units of on-board relays of the AR 40B will be substituted with optocouplers to prevent dangerous voltage spikes from reaching the microcontroller and its associated control circuit.
Objective 4: Testing on robots.	The finished robot controller will be tested on robots to prove its capability.

Objective 5: Producing a technical guide.	A technical guide will be produced, complete with product specifications and troubleshooting guide to aid the user in pin pointing any problems that may arise.

1.4 Scopes

The scope of the project defines limitations of this project in terms of design considerations and the type of hardwares that will be produced. The following is a table detailing the break down of the scopes of the project.

Table 1.2: The break down of the scopes of the project.

Scope	**Description**
Scope 1: Deliverables of the project.	The 2 deliverables of the project is a robot controller in hardware form built on printed circuit board and a technical guide. The robot controller only process inputs and outputs from the robot. Any external circuits which may be required, such as external stepper motor drivers or analog sensors circuit, will not be built as part of the package of the controller.
Scope 2: Power source.	The power source of the robot controller can be a 9V or 12V battery. The robot controller can only be powered DC source.
Scope 3: Sensors types.	The robot controller can be wired to digital sensors (output = +5V or 0V) and analog sensors (output = a range of values between +5V and 0V). More complex sensors such as an RGB camera will not be supported by the robot controller.
Scope 4: Supported motor types.	The robot controller will be able to control brushless DC motor, brushed DC motor, stepper motor, and servomotor. The robot controller will communicate with the servo motor driver via the Tx/Rx output pins. The control of AC motors will not be supported.

Scope 5: Supported microcontroller types.	The supported microcontroller is a 40-pins PIC 18F4431 from Microchip and it cannot be substituted with another 40 pins microcontroller without having the system suffering degradation in performance.
Scope 6: USB In-Circuit-Serial-Programmer.	The on-board USB ICSP design and its related software and program will be sourced from established design.

1.5 Project Background

The robot controller is a device that can be defined as the brain of a robot. It essentially processes the inputs from the robot according to the program written by the user and produces the desired outputs so that the robots will execute required action. The robot controller can take many forms, such as programmable logic controller, microcontroller, and computer based applications. In this project, the PIC18F 4431 is chosen to be used in the robot controller. Other popular microcontrollers for use in robot control are Intel's 8051 and Atmel's range of Atmega MCU.

The main purpose of the robot controller is to accept inputs from the sensors and deliver outputs to activate peripherals on the robots, such as motor drives and blinking lights. The way the robot behaves is governed by a piece of software written onto the flash memory of the microcontroller through a programmer. The advantage of having flash memory is that it can be erased and reprogrammed a vast number of times. Conventionally, the microcontroller needs to be removed from its board to be programmed on a serial programmer. However with the advent of USB ICSP programmer, it is now possible to download program into the microcontroller without having to remove it from its board.

Just like human who can see, hear, and touch, the robot controller senses the conditions of the environments through a wide array of sensors. The types of sensors can be categorized into 2 groups – analog and digital sensors. Examples of analog sensors are temperature sensors, proximity sensors, infrared sensors, and potentiometer. An external drive circuit is required to convert the analog sensors into a range of voltages between 0V and 5V. The robot controller will then read the values in steps through its analog-to-digital channel. On the other hand, digital sensors output a voltage that is either 0V or 5V. The sensors included in this category are push buttons, contact switch, limit switch, keypads, and so on.

The outputs of the microcontroller are only digital in nature as there is no analog output. The output can be used to drive a range of peripherals such as light display, motor drives, and sound speaker. Usually, an external drive circuit is needed as an intermediate between the peripheral and the microcontroller as the current from the output ports are limited. For example the H-bridge driver is usually used for driving DC motor instead of connecting the DC motor directly to the ports of the microcontroller. Though the microcontroller is not capable of analog outputs, there is a method called Pulse-Width-Modulation (PWM) which utilized pulses of signals between 0V and 5V to generate a range of average output voltages. The characteristics of the PWM can be modified by changing its frequency and duty cycle.

In this project, the PIC18F4431 microcontroller used is able to generate 4 independent power control PWM and 2 CCP PWM, bringing the total of PWM output channels to 6. Even though the typical autonomous robots utilizing differential drive can needs only 2 PWM channels, certain robot application such as the mecanum wheel robot will require 4 PWM channels to control it multiple DC motor driver, as described in [2]. The other additional feature of the project's robot controller is that optocouplers are used in place of relays. The optocouplers eliminates "ohmic contact" and transfer signals through an LED light beams across an electrically isolated space to a photodiode. Furthermore the optocoupler can offer higher frequency switching rate than the relays.

The robot controller is usually mounted on the physical structure of the mobile robots. The locomotive motion of the robot may come from wheels, belt tracks, or legged structure design. An onboard battery will be on board the robot to provide power to the robot controller and the associated peripherals. The normal choices of rechargeable batteries are nickel cadmium battery pack, lead acid batter, and lithium ion batter pack. If the voltage supplied by the battery is more than 12V, a voltage regulator will be in place to step down the voltage.

1.6 Literature Review

For the purpose of this project, literature reviews have been done to source for research articles concerning robots controllers and multiple DC motor control in order to explore fresh ideas and strengthen the basis upon which this project is built on. The following review has been done on this research..

1.6.1 The Use of PIC Microcontrollers in Multiple DC Motors Control

This research article, dated July 2007 through September 2007, is written by Dr. Steve Huang who is an associate professor of electrical engineering technology at Old Dominion University, USA. In this article, he presented a solution for simplifying the control of multiple DC motors using multiple small scale microcontrollers system for use in complex project conditions. Essentially, his design implements a master/slave concept where one microcontroller is designated as the master to control and link together other slave microcontrollers. The master microcontroller and the slave microcontroller are of the same model – PIC16F84A. The master microcontroller is connected to an LCD screen and a keypad so that the user can directly key in the command parameters while the slave microcontroller is dedicated to controlling one motor each. After the user has key in the instructions, the master microcontroller will communicate with all the slave drivers through serial UART communication to pass on the command. Each slave microcontroller has been assigned an address so that it will only process the relevant instructions intended for it. The serial data transmitted contain the address of the slave microcontroller and the speed/rotation/running period of the intended motor.

The benefits of this system design is that it implemented a modular design whereby a virtually unlimited amount of slave microcontroller can be added into the system with minimal modifications required for the system, both hardware and software-wise. Thus, this is a versatile system that can be adapted into a robot controller design where the robot builders have the options of increasing the amount of motor drives without having to worry about robot controller design constraint. This is a luxury that is not provided by conventional robot controllers where the total available control pins of the microcontroller are fixed/limited, thus offering no room for expansion to accommodate any extra motor drives after the limit of the pin counts has been reached.

The possible downside that may arise from this system design is that miscommunication may arise as all the slaves will only start to execute the received command after the master has accepted acknowledgements signal from all the slaves. Thus if, due to some technicalities, one of the slave consistently fail to return the acknowledgement signal, then the entire operation will be halted. Furthermore, the use of the 16F84A microcontroller as dedicated slave motor control is not suitable as the microcontroller does not have built in PWM functions. Thus improvisation is done by using Timer0 and interrupt functions to produce PWM signals, which will burden the user with additional programming efforts.

From this piece of article reviewed, the point which can be incorporated into this project is to use serial UART communication to control an external slave servomotor driver. Furthermore, the similarity with this project is that LCD screen and keypad are used for inputting software parameters.

CHAPTER 2

MATERIALS AND METHODOLOGY

2.1 Methodology Overview

The steps that should be taken in order to produce the final outcome of the project can be broadly categorized into 3 phases, which are:

i. Study and information gathering.
ii. Designing and testing of the individual modules.
iii. Fabricating the controller board using PCB method and further verification testing on finished product.

The following flow chart shows the overall process of the methodology in producing the robot controller.

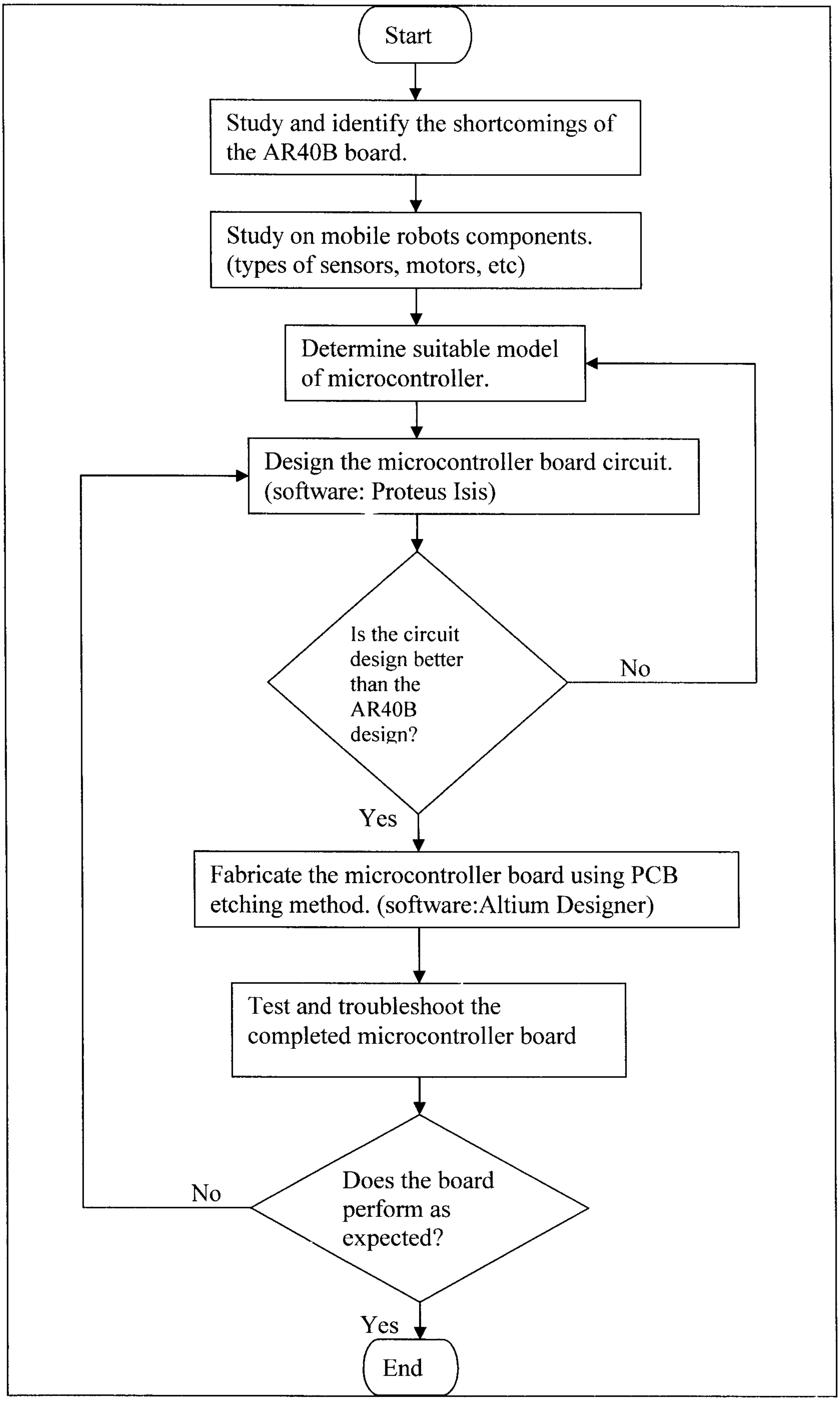

Figure 2.1: The overall flowchart of the methodology process.

2.2 Development of the Project's Hardware

2.2.1 Designing of the PCB Schematic Using Ares

The PCB schematic, also known as the artwork, was drawn using the PCB CAD software Ares. This program contains commonly used PCB package sizes as well as a comprehensive set of tools for drawing the circuit with ease.

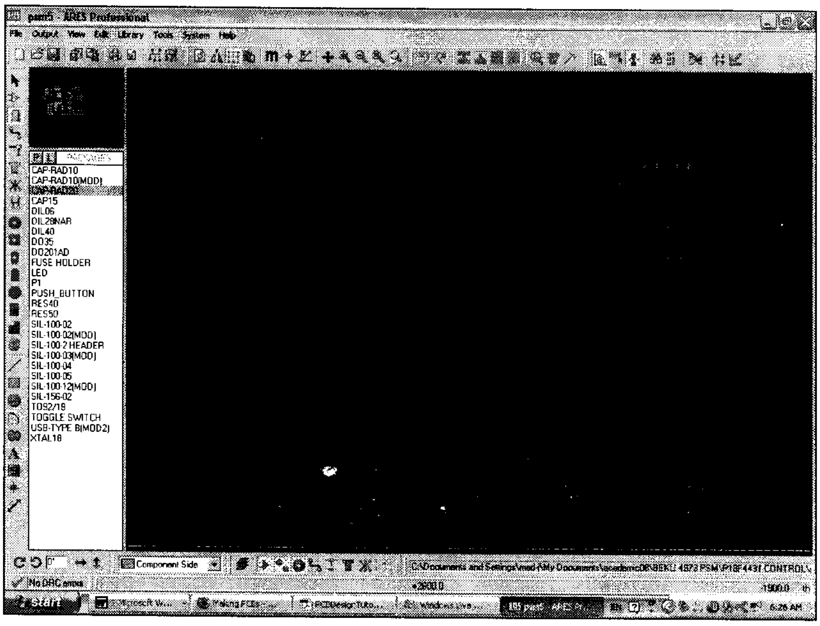

Figure 2.2: The screen shot of the Ares PCB CAD program.

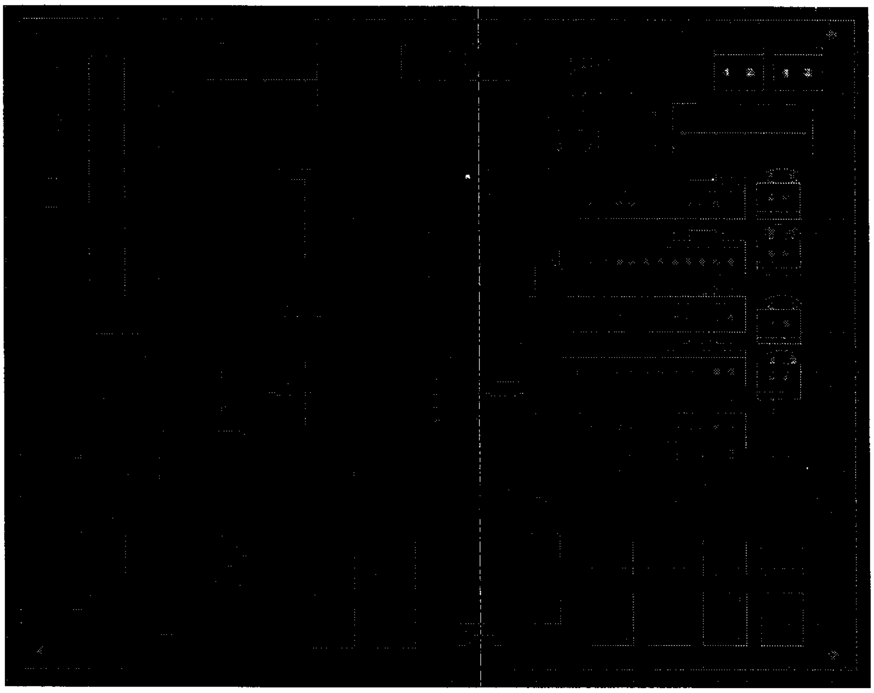

Figure 2.3: The PCB schematic of the controller circuit.

The following diagram shows the elements that were fundamental to the design of PCB schematic.

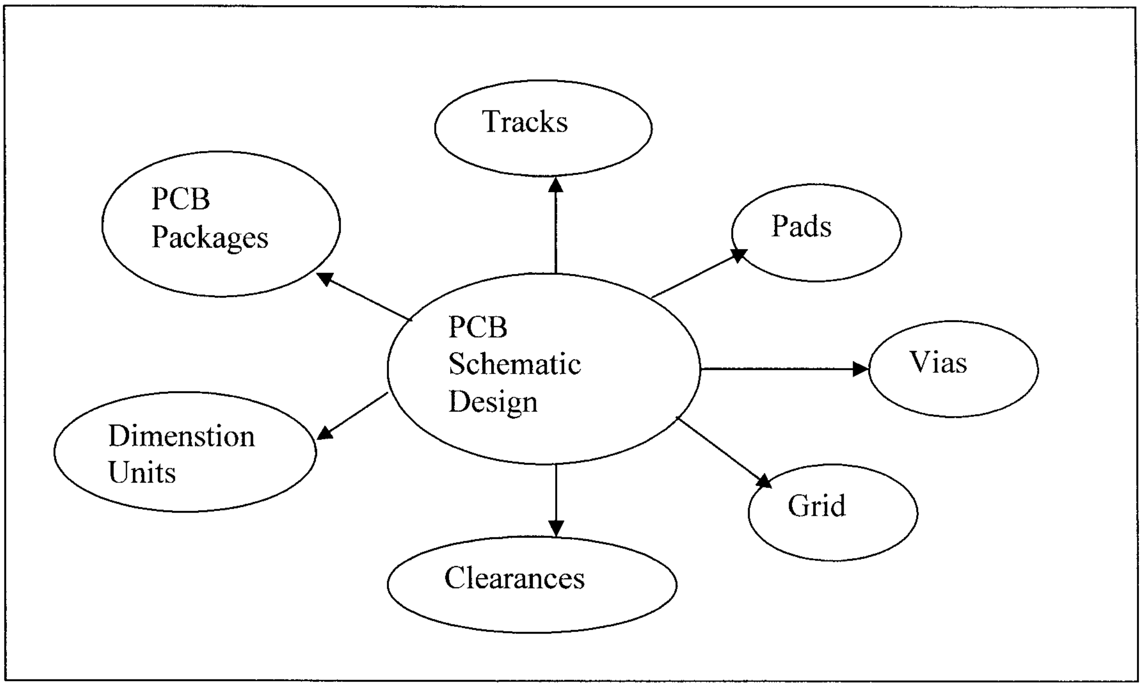

Figure 2.4: The elements needed to produce a PCB schematic design