DEVELOPMENT OF AUTO RE-CLOSER EARTH LEAKAGE CIRCUIT BREAKER (AR-ELCB)

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Signature : ______________________________

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Date : 28 APRIL 2009

Dedicated to
my beloved mother,Yan Bte Awang,
lecturers and friends
for giving a constant source of support and encouragement.

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Lastly, thanks to my father, mother and my siblings who were constant and active source of support throughout the endeavor.

ABSTRACT

An Earth Leakage Circuit Breaker (ELCB) is an electrical device that disconnects protected circuit whenever it detects unbalance current between the phase conductor and the neutral conductor. Such an unbalance is sometimes caused by current leakage through the body of a person who is grounded when accidentally touching the energized part of the circuit. A lethal shock can result from these conditions. ELCB are designed to disconnect this fault fast enough to mitigate the harm caused by such shocks. Currently, there is no Earth Leakage Circuit Breaker (ELCB) with auto re-closer features in the market. The current ELCB that available in the market is a manual type and cannot differentiate between temporary disturbances and permanent faults. It's means that, if a disturbance or fault occurs on the protected area (house or shop), the protection system will force ELCB to trip. One of the drawbacks of the common ELCB is that, it's can't turn on the power supply back to the normal operation condition although only a short disturbance occurs. Such disturbance is lightning strike on the transmission line in the distribution site near to the protected area. To turn the power back to normal operation, consumers need to do that manually. To overcome this problem, Auto Re-closer Earth Leakage Circuit Breaker (AR-ELCB) has been developed. This thesis presents the development of AR-ELCB. This device was designed to differentiate between permanent fault and short disturbances (lightning).

ABSTRAK

Alat pemutus litar bocor ke bumi (ELCB) ialah sejenis alat yang akan memutuskan litar yang dilindungi apabila ianya mengesan sebarang ketidakstabilan arus antara fasa konduktor dan neutral konduktor. Ketidakstabilan arus biasanya disebabkan oleh kebocoran arus menerusi badan manusia yang secara tidak sengaja tersentuh bahagian litar yang sedang aktif. Ianya boleh menghasilkan kejutan arus elektrik yang membawa kepada maut. ELCB dicipta untuk memutuskan kesilapan ini secepat yang mungkin untuk mengurangkan bahaya yang dihasilkan oleh kesilapan sedemikian. Pada masa sekarang, masih tiada lagi alat pemutus litar kebocoran bumi (ELCB) dengan fungsi penutup automatik di pasaran. ELCB yang terdapat di pasaran sekarang adalah dari jenis yang manual dan tidak dapat membezakan antara gangguan sementara ataupun kerosakan berkekalan. Ini bermakna, jika gangguan ataupun kesilapan berlaku di kawasan perlindungan (rumah ataupun kedai), sistem perlindungan akan menyebabkan ELCB memutuskan litar. Salah satu kekurangan pada ELCB yang biasa ialah, ia tidak boleh mengembalikan bekalan arus kepada keadaan operasi biasa walaupun gangguan yang berlaku hanyalah gangguan kecil sahaja. Contohnya gangguan oleh kilat yang menyambar pada saluran pangiriman di tapak pembahagian arus elektrik berhampiran dengan kawasan perlindungan. Untuk menghidupkan bekalan arus balik pelanggan mestilah melakukannya secara manual. Untuk mengatasi masalah ini alat penutup automatik pemutus litar bocor ke bumi (AR-ELCB) telah dibangunkan. Tesis ini membentangkan tentang pembangunan AR-ELCB. Alat ini dicipta untuk membezakan antara kerosakan berkekalan ataupun gangguan sebentar (kilat).

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V	–	Voltage
ac	–	Alternating Current
dc	–	Direct Current
Ω	–	Ohm
I_i	–	Input Current
Io	–	Output Current
V_{in}	–	Input Voltage
V_o	–	Output Voltage
R_L	–	Load Resistor

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CHAPTER 1

INTRODUCTION

1.1. Project Background

An earth leakage circuit breaker (ELCB), or residual current circuit breaker (RCCB), is an electrical wiring device that disconnects a circuit whenever it detects that the electric current is not balanced between the Live conductor and the Neutral conductor.

ELCB is a tool which helps to prevent electric shock. It will act to cut the electricity supply off to your house if there were any damages to assembly or electrical appliances such as leakage current to earth through live wire contact to electrical appliances frame which could expose the consumer to electric shock. If the wiring at your house is not fitted perfectly or the electrical appliances are low quality, there are probabilities of high current leakage to earth. This could cause electric shock as those described above and could also cause the fire if this state is protracted in the environment which sensitive with heat.

My project is aim to design and develop a unit of auto re-closer earth leakage circuit breaker (ELCB) that can differentiate and act differently with different types of fault. The concept is if there are faulty occurred, the ELCB will trip, if the fault is from temporary fault type like lightning, ELCB will close back automatically after three seconds. But if the faulty is eternal/permanent fault like from electrical, electronic device or short circuit ELCB will eternally trip and the permanent warning light will on until the fault root cause is cleared and the switch is “on” back by someone again. In this project we have planned to use the microcontroller as a control element.

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1.2. Objectives

The objectives of this project are:

i) To design an ELCB with an auto re-closer unit.
ii) To develop an ARELCB unit.
iii) To fabricate ARELCB for demonstration purpose.

1.3. Scope of Project

The objectives of this project are:

i) The scope of this project is to improve the currently ELCB so that the new ELCB has the ability to turn on back after being trip.
ii) The ARELCB can also distinguish either it is permanent fault or moment fault that occur, so that it will only trigger on when necessary.
iii) To ensure this project work perfectly, Programmable Interface Controller (PIC) and programming will be implement along this project.

1.4. Literature Review

ELCB operate by measuring the current balance between two conductors using a differential current transformer. The device will open its contacts when it detects a difference in current between the line conductor and the neutral conductor. The supply and return currents must sum to zero, otherwise there is a leakage of current to somewhere else (to earth/ground, or to another circuit, etc.).[1]

ELCB is designed to prevent electrocution by detecting the leakage current, which can be far smaller (typically 5–30 milliamperes) than the currents needed to operate conventional circuit breakers or fuses (several amperes). RCDs (Residential Current Device) are intended to operate within 25–40 milliseconds, before electric shock can drive the heart into ventricular fibrillation, the most common cause of death through electric shock.[1]

In the United States, the National Electrical Code, requires GFCI (Ground Fault circuit Interrupter) devices intended to protect people to interrupt the circuit if the leakage current exceeds a range of 4–6 mA of current (the trip setting is typically 5 mA) within 25 milliseconds. ELCB devices which protect equipment (not people) are allowed to trip as high as 30 mA of current. In Europe, the commonly used RCD have trip currents of 10–300 mA.[2]

Residual current detection is complementary to over-current detection. Residual current detection cannot provide protection for overload or short-circuit currents.

ELCB with trip currents as high as 500 mA are sometimes deployed in environments (such as computing centers) where a lower threshold would carry an unacceptable risk of accidental trips. These high-current ELCB serve more as an additional fire-safety protection than as an effective protection against the risks of electrical shocks.[2]

For many years, the voltage operated ELCB and the differential current operated ELCB were both referred to as ELCBs because it was a simpler name to remember. However, the use of a common name for two different devices gave rise to considerable confusion in the electrical industry. If the wrong type was used on an installation, the level of protection given could be substantially less than that intended. To remove this confusion, IEC decided to apply the term Residual Current Device (RCD) to differential current operated ELCBs. Residual current refers to any current over and above the load current. [2]

1.5 Thesis Outline

Chapter 1 discuss about the project background, literature review like the history of ELCB, objective and scope of the project.

Chapters 2 discuss about of Earth Leakage Circuit Breaker (ELCB), the design, the component inside it and also the operation. Besides, this chapter also states the problem with ELCB that make us want to integrate it and about electric fault.

Chapter 3 explains more on the designing and operation of the new AR-ELCB systems. It also describe the functions of each components used in the circuit especially on the ARELCB stage circuit

Chapter 4 describes about another circuit in this project, the control circuit which has PIC18F4550 as the brain of this project. The hardware and the programming software detailed in this topic.

Chapter 5 presents the data and result that have been recorded from the study and some experiments while in development process. The result of this project also is accompanied by the discussions for each problem statements.

Finally in chapter 6, the conclusion has been made for the project from each aspect and there are also suggestions to improve the AR-ELCB on the future, for the commercialization. Costing data also stated in this chapter.

CHAPTER 2

EARTH LEAKAGE CIRCUIT BREAKER

2.1. Introduction

An Earth Leakage Circuit Breaker (ELCB) is a device used to directly detect currents leaking to earth from an installation and cut the power. It was mainly used in TT earthing systems.

In a TT earthing system, the protective earth connection of the consumer is provided by a local connection to earth, independent of any earth connection at the generator.

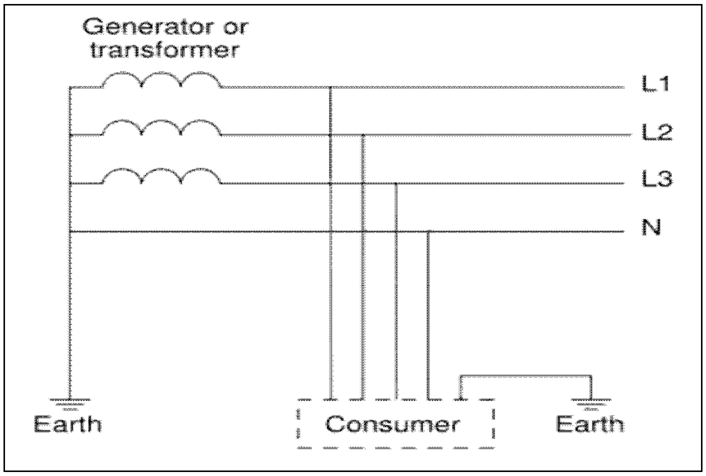

Figure 2.1: TT network

The device could detect the leakage current and protect consumer from electrical shock if leakage current occurred to the consumer equipments. This device will cut off the electrical supply instantaneously when current leakage is detected. There are two types of ELCB:

i) Voltage Earth Leakage Circuit Breaker (vELCB)

ii) Current Earth Leakage Circuit Breaker (iELCB)

2.2 vELCB

vELCB is a voltage operated circuit breaker, the device will function when the Current passes through the ELCB. vELCB contains relay loop which it being connected to the metallic load body at one end and it is connected to ground wire at the other end. If the voltage of the load body is rise which could cause the difference between earth and load body voltage, the danger of electric shock will occur. This voltage difference will produce an electric current from the load metallic body passes the relay loop and to earth. When voltage on the load metallic body raised to the danger level which exceed to 50Volt, the flowing current through relay loop could move the relay contact by disconnecting the supply current to avoid from any danger electric shock.

2.3 iELCB

iELCB is current operated circuit breaker. Current-operated ELCBs are generally known today as RCD (residual current device). These also protect against earth leakage, though the details and method of operation are different. The device will function with when the Current passes through ELCB. This current admitted to current transform device and on the load. Current from the load also admitted again to transform device. In normal state, total current applied to load is equal with total current out of the load. Because of the balance of in and out of current, it does not affect the current transform device. If there is any earth current leakage caused by earth damage, then the in and out current will no longer in balance. This unbalance current phenomenon will generate the current and if the current exceeded the prescribed rate, the ELCB will jerked and cut off the supply. The device also being called RCD, Residual Current Device in IEC or RCCB, Residual Current Circuit Breaker.

2.4 Problem statements

This device is using mechanical switch that must be switch on manually, after ELCB is being tripped it will stay off until there is someone turn on it back although the problem that occurred is temporary fault and occurred in few millisecond. So, it not works as intelligent device that can operate automatically.

The other problem is ELCB can not distinguish whether the fault is temporary or permanent fault where there are the differentiations between these two types. And do not act differently for these two types of faulty.

2.5. Fault

A fault is any abnormal situation in an electrical system in which the electrical current may or may not flow through the intended parts. Also equipment failure attributable to some defect in a circuit (loose connection or insulation failure or short circuit etc). Types of faults in a distribution network circuit are:

i) Over-load
ii) Line to line fault
iii) Single lines to ground fault
iv) Double line to ground fault

Over-load faults are caused by the unexpected increasing of loads. Faults on electrical equipments are caused by lightning, insulator breakage, Product design which is out of specification and Improper installations of equipments.

Most faults on transmission lines of 100kV and higher are caused by lightning, which results in the flash over of insulators. Transmission lines faults are caused by, lightning, storm, fallen trees, Snow. One of the temporary fault, is a fault lightning. Where example of permanent fault is faults on electrical equipment.

2.6 ELCB Design

Figure 2.2 shows the original of ELCB, the design consists of mechanical switch, ZCT, yellow/ black Box, High level transistor and the reset button. Mechanical switch is a contact of black box, the function of this component is to trigger and cut off the power with cut off the life and neutral line altogether. The function of high level transistor is to limit the current flowing through its line when the reset button is pushed.

Then the ZCT, the function of this component is to detect the unbalance current in the system and send the signal (induced current) to Black Box. In a black box there is a coil, the coil will activate the mechanical switch after received the minimum current level 100mA (theoretically) from the ZCT. Lastly, there is also reset button, the function of the reset button is to re-set back the device to the initial condition and also as a point to detect whether the device still in good condition or damage/expired. Figure 2.3 show the block diagram of ELCB circuit.

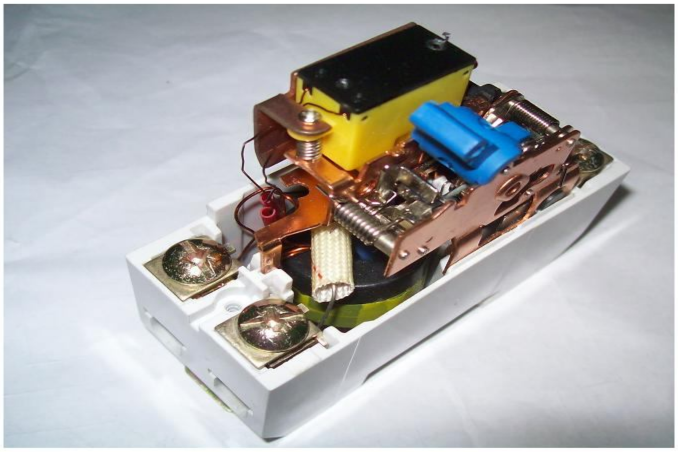

Figure 2.2: Original ELCB

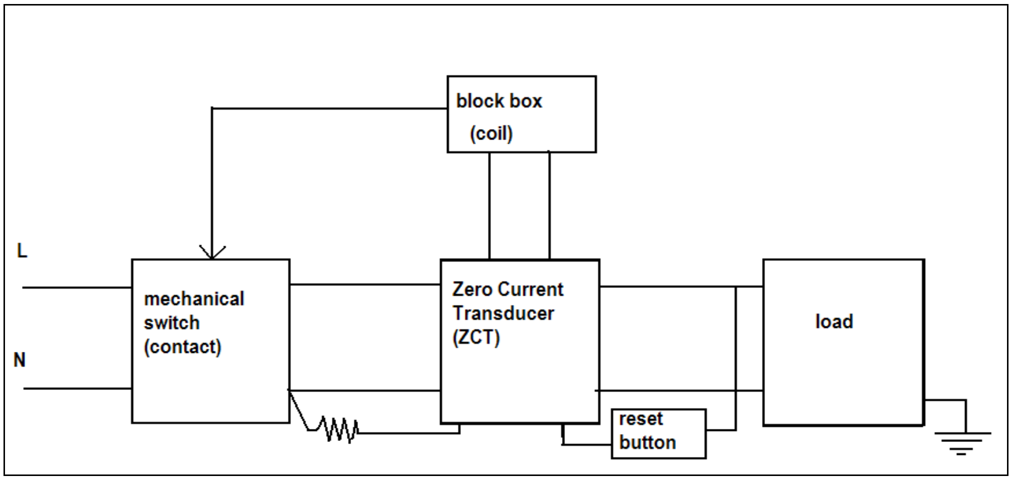

Figure 2.3: Earth Leakage Circuit Breaker design

2.7 Component of ELCB

Old ELCB contain these components to operate:

2.7.1. Zero Current Transducer (ZCT)

The function of this component is to detect the unbalance current in the system and send the signal (induced current) to coil.

2.7.2. Mechanical switch

Mechanical switch is a contact of black box, the function of this component is to trigger and cut off the power with cut off the life and neutral line altogether.

2.7.3. Coil

In a black/yellow box there is a coil, the function of black box is received the signal (induced current) from zero transducer current. The coil is to contact with mechanical switch.

2.7.4. Reset Button

Function of the reset button is to re-set back the device to the initial condition and also as a point to detect whether the device still in good condition or damage/expired.

2.7.5. High Level Resistor

Function of high level resistor is to limit the current flowing through its line when the reset button is pushed.

2.8 Operation of ELCB

When the faulty occurred, there are imbalance value of current in L and N and ZCT will detect it, so the induced current will happened in ZCT, induced current that reached the min value to activate the coil will be send as a signal to the Black Box, when the coil is activated, it will sense the contact to trigger and automatically the mechanical switch is triggered and this will cut off the supply from main line.

An ELCB is a specialized type of latching relay that has a building's incoming mains power connected through its switching contacts so that the ELCB disconnects the power in an earth leakage (unsafe) condition.

The ELCB detects fault currents from live to the earth wire within the installation it protects. If sufficient voltage appears across the ELCB's sense coil, it will switch off the power, and remain off until manually reset. An ELCB however, does not sense fault currents from live to any other earthed body.

2.9 Summary

Basically, ELCB have two type like above, both device used for protection device for electrical equipment and for safety for human being from fatality hazard. By the way, each device has a little differentiation in operation. If there are the faulty occurred the device will with cut off the supply in the main line. So the equipment will be safe. ELCB also must be able to act differently between permanent fault and temporary fault. It can improve ELCB ability and can its function.

CHAPTER 3

AUTO RECLOSER EARTH LEAKAGE CIRCUIT BREAKER DESIGN

3.1 Flowcharts of work plan

Before ARELCB designed, plan to do this project must be arrange to optimize the time before the due date. First, basic ELCB must be explored to know the basic operation and the component should be used in new ARELCB. Second, the circuit designed followed by suitable controlled circuit to accompany the ARELCB circuit to make it function correctly. Then, the flowchart of programming created to easy the programming process. After the circuit complete, data from ARELCB collected by measure the current induce in ZCT, the output voltage tripped range in Op-amp and the relation of Rl and output voltage from Op-amp.

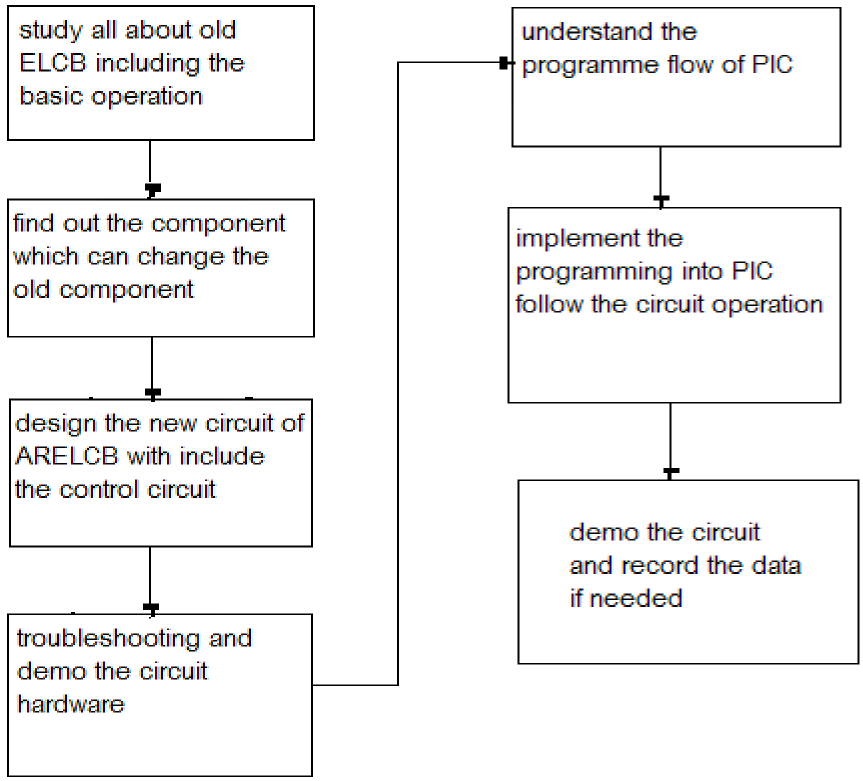

Figure 3.1: Flowchart of work plan

3.2 First design of ARELCB circuit

From the circuit, transformer and rectifier work as the step down device to produce power supply to control circuit which use only 5V DC. Then, only one line, (life) flow trough the relay because we only need to cut off one line to make the power line in off state. Current transducer used to measure the range of current in neutral line and send it to microcontroller. Lightning protection device is important to protect the circuit from the over current from the lightning.

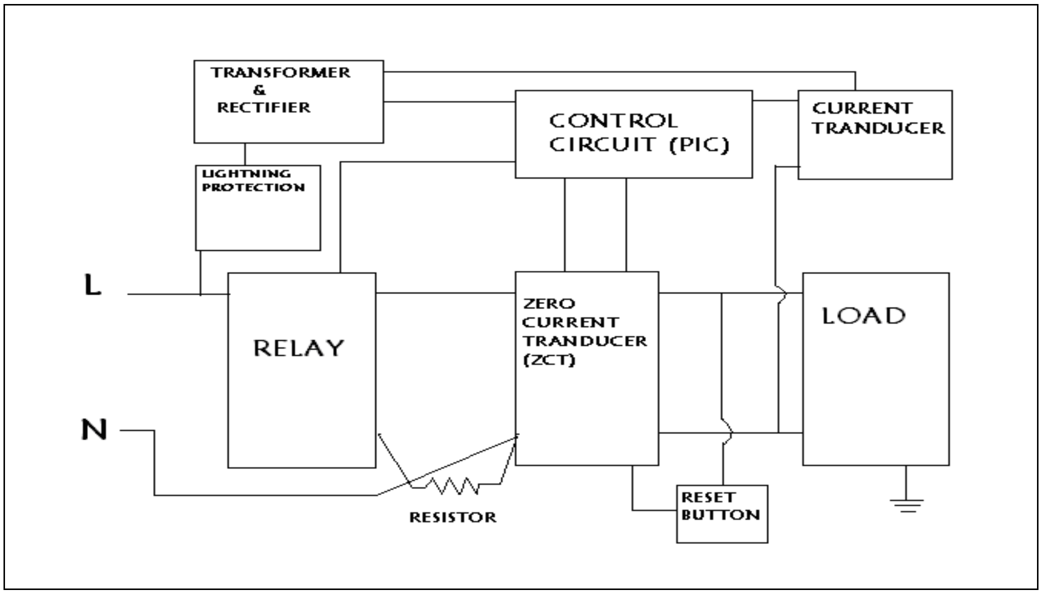

Figure 3.2: Early ARELCB circuit design

3.3 Final design of ARELCB circuit

After a lot of test and study, there are some changes in ARELCB circuit to decide as finalize design. First, separate power supply create for main circuit and control circuit because, there has voltage drop at control circuit supply cause by energize of 12V DPDT relay. When a relay energized, it will absorbed a lot of power supply cause by coil in it. Another 5V relay also put before the 12V DPDT relay to make it in normally close condition.

Converter op-amp used to convert the current signal from zero current transducer to produce voltage signal to send to microcontroller. It also accompanied by variable resistor to boost the voltage output to reliable value.

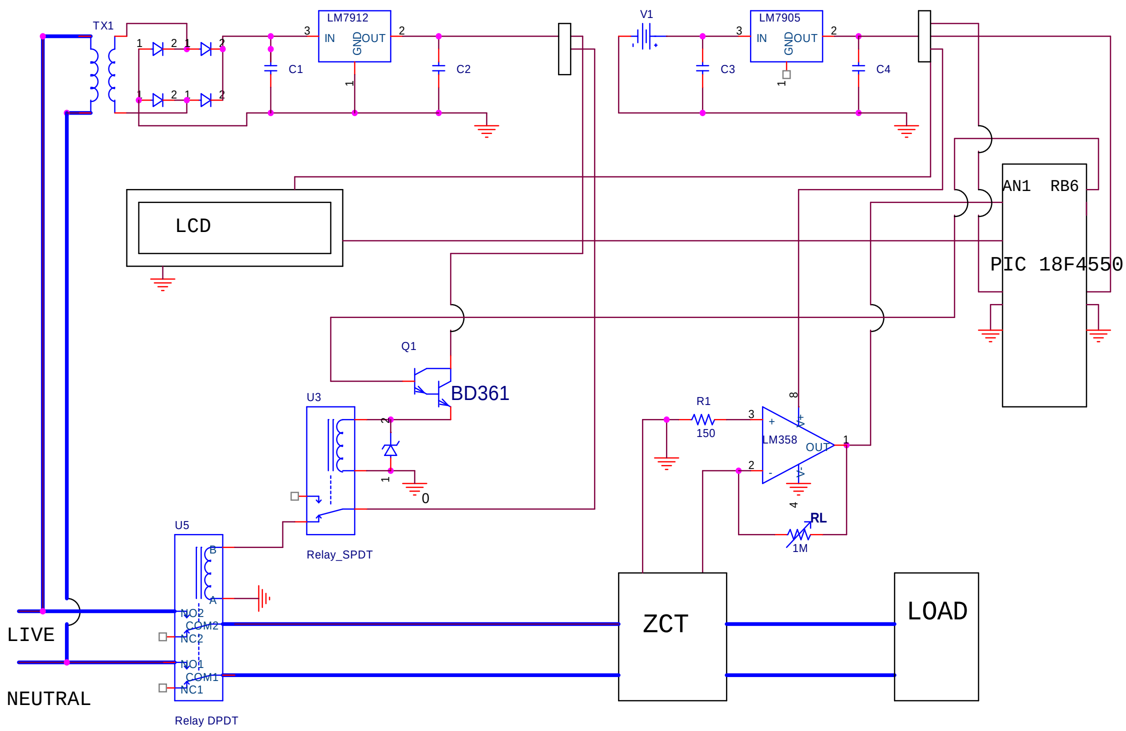

Figure 3.3: Final circuit of ARELCB

3.4 Control and display circuit

Figure above show the connection between microcontroller (PIC 18f4550) and LCD. Also show output from Op-amp to PIC18f4550 and from PIC18f4550 to Darlington diode. For LCD, only use 4 bit to display because it very simple and easy to make the programmed. So, there are 10 pin used in this connection which include pin RB0 until RB7 except RB1 and RB2.

Pin RB1 used to send digital output signal to Darlington diode to energize relay as the main output of the system while RB2 used for red LED for indicator when the circuit trip. RA1 used for analog input from Op-amp which sends voltage in range

1Volt until 2Volt. The crystal oscillator selected for this PIC18f4550 is 20 MHz and connected to pin 13 and 14.

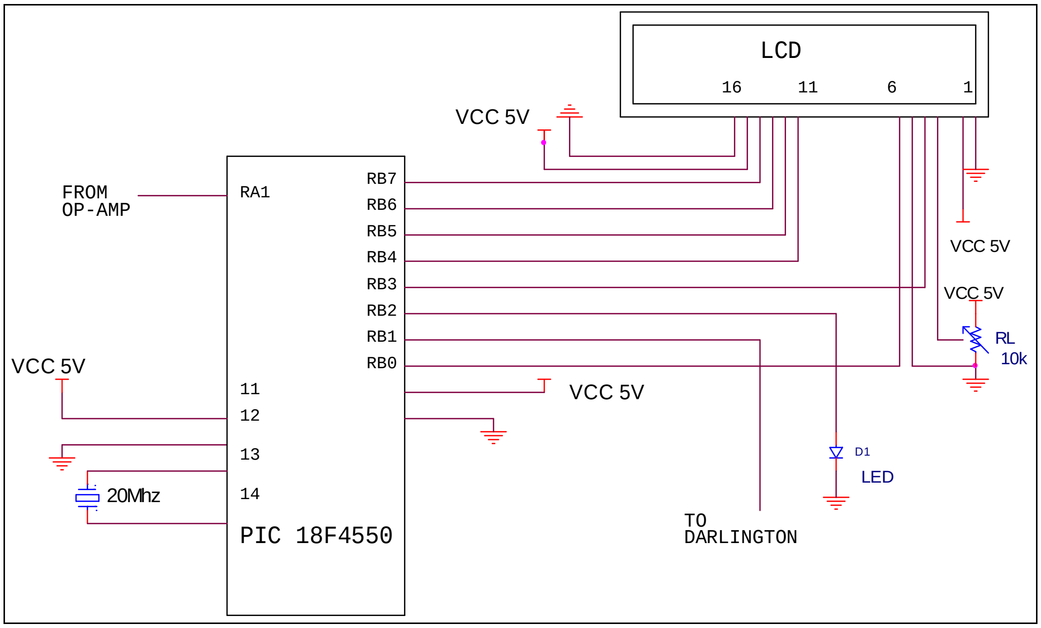

Figure 3.4: Microcontroller circuit and LCD

3.5 Components of ARELCB

ARELCB need these components to work based on circuit:

3.5.1 DPNO Power Relay

This type of relay has double pole normally open connection and the contact can hold maximum voltage at 250Vac. For maximum current rating, it can operate for 25-30A and need 8-12Vdc for the coil. The coil resistance is 750ohm.

Figure 3.5: DPNO power relay

Table 3.1: Specification of DPNO power relay

Type	HY1A	HY2A
Rated load	Res. 30A, 250VAC/Ind. 25A,. 250VAC COS Ø0.4	Res. 25A, 250VAC/Ind. 25A, 250VAC COS Ø0.4
Rated current	30A	25A
Maximum switching voltage	277VAC	
Maximum switching capacity	7500VA	6250VA
Operate time	30ms max	
Release time	30ms max	
Dielectric strength	4000V, 50/60Hz for 1 min (coil to contact)	
Ambient operating temperature	-55~+70C (no freezing)	
Mechanical service life	10,000,000 operations min	
Electrical service life	100,000 operations min	
Contact material	AgSnO	
Voltage range	AC80~110%, DC75~110%	
Power consumption	Approx. 1.7VA~2.7VA/1.9W	
Weight	Approx. 120g	

3.5.2 230/15 VAC Transformer

Figure 3.6 shows transformer, it is one type of transformer that used to reduce the voltage from 230Vac to 15Vac and supply the voltage to the power supply circuit. It is the most comprehensive choice of secondary voltages. It also is flame retardant bobbins and shrouds.

Figure 3.6: 230/15 VAC Transformer

Table 3.2: 230/15 VAC transformer

Weight	0.4	KG
Typical regulation	12	%
Frequency	50/60	Hz
Max Ambient	25	°C
Bobbin Material	UL94-V0 Class "B" 130°C	

3.5.3 Zero Current Transducer (ZCT)

Figure 3.7 shows the ZCT, the function of ZCT is to detect the unbalanced current between life (L) and neutral (N) line. Then the induced current will be sent to converter circuit, the polarity connection of this device must be invert so that the positive supply will be produce from converter circuit.

Figure 3.7: Zero Current Transducer

3.5.4 Bridge rectifier

Refer to the Figure 3.8 it is the KBPC3510 Bridge model, it is used to rectify the voltage from AC supply to DC power supply for IC voltage regulator device. This AR-ELCB need two bridges because it was used both PCB MOUNTING output terminals.

Figure 3.8: Bridge rectifier

3.5.5 Voltage regulator

In this project two power supply circuit designed which are 8V and 5V. So, two voltage regulators used which are LM7808 to produce 8V output and LM7805 to produce 5V output. Both is same for the physical, have 3 terminal but different voltage output.

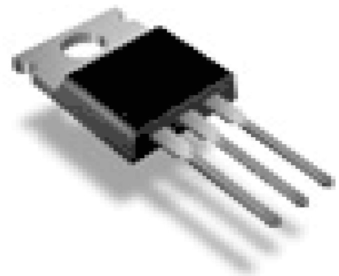

Figure 3.9: LM780X

3.5.6 BD681 Darlington Transistor

Figure 3.10 shows the BD681, it is a silicon epitaxial base NPN power transistors in monolithic Darlington configuration mounted in Jade SOT-32 plastic package. They are intended for use in medium power liner and switching applications. BD681 was used as the intermediary between PIC18f4550 and DPNO power relay. It will drive the high current from power supply and function when 8V output voltage from microcontroller is supplied to it.

Figure 3.10: BD681 Darlington Transistor

3.5.7 TRD-5VDC-FB-CL relay

Figure 3.11 shows the TRD-5VDC-FB-CL relay, this device function as a driver in the second stage circuit, it is use to be the intermediary between Heavy Duty Power Relay with microcontroller and with main power supply. For this AR-ELCB circuit, 5V relay must be installed in normally closed condition.

Figure 3.11: 5Vdc Relay

3.5.8 LM358N Operational amplifier

These circuits consist of two independent, high gains, internally frequency compensated which were designed specifically to operate from a single power supply over a wide range of voltages. The low power supply drain is independent of the magnitude of the power supply voltage. Application areas include transducer amplifiers, dc gain blocks and all the conventional op-amp circuits which now can be more easily implemented in single power supply systems. For example, these circuits can be directly supplied with the standard +5V which are used in logic systems and will easily provide the required interface electronics without requiring any additional power supply. In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.

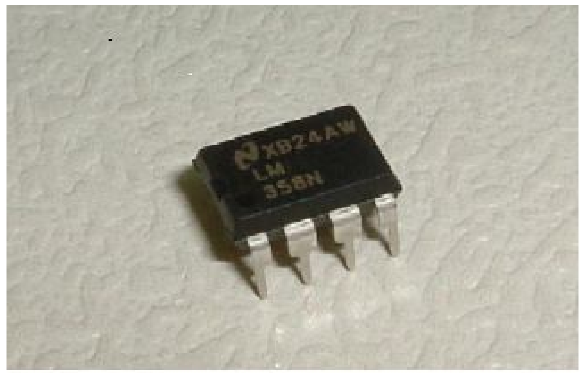

Figure 3.12: BD681 low power dual operational amplifier

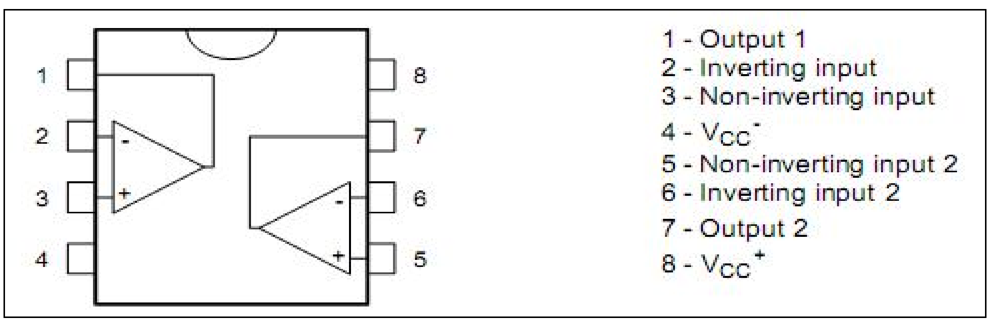

Figure 3.13: internal connection of LM358

3.5.9 Liquid crystal display (LCD)

Liquid crystal display used is 4 bit and consist two rows of display. 5V power supply used in two port and it must be accompanied by variable resistor to control the contrast of the display. This is important because without variable resistor, display might be not clear or faint.

Figure 3.14: Liquid crystal display (LCD)

3.5.10 Light Emitting Diode (LED)

LED is a semiconductor diode that emits light when an electric current is applied in the forward direction of the device, as in the simple LED circuit. The effect is a form of electroluminescence where incoherent and narrow-spectrum light is emitted from the p-n junction.

Figure 3.15: Light Emitting Diode (LED)

In this project, the green LED was used to show that there are lightning occur, and the circuit trigger will re-close back after 9.8 seconds. Besides the red LED is use to show that there are short circuit or permanent fault occur and the circuit will permanently cut-off the incoming supply until the fault root cause is remove and the reset button is pushed by someone.

3.5.11 9 Volt battery

This battery used to supply to control unit circuit which use 5V by regulated by LM7805 voltage regulator. A 9 volt battery, sometimes referred to as a PP3 battery, is shaped as a rounded rectangular prism and has a nominal output of nine volts. Its nominal dimensions are 48 mm × 25 mm × 15 mm (ANSI standard 1604A)

Figure 3.16: 9V battery

3.6 Operation Process

ARELCB works started with the supply voltage from outside power line, and then the supply will flow to the system through DPNO power relay, the function of this relay is as main switch for the whole residential supply system. If the unbalanced current between life and neutral line occurred and the value reached Δ100mA, the current will be induced automatically in the ZCT and transferred to the converter circuit. Then the output voltage will be sending the signal of 5V to the microcontroller. All command process will be done like programmed in the microcontroller, microcontroller will identify what type of output that will be sent to the driver due to programmed software. Then the output will be send to the Darlington diode as the driver, and driver will energize the 5V relay which will open the DPNO power relay.

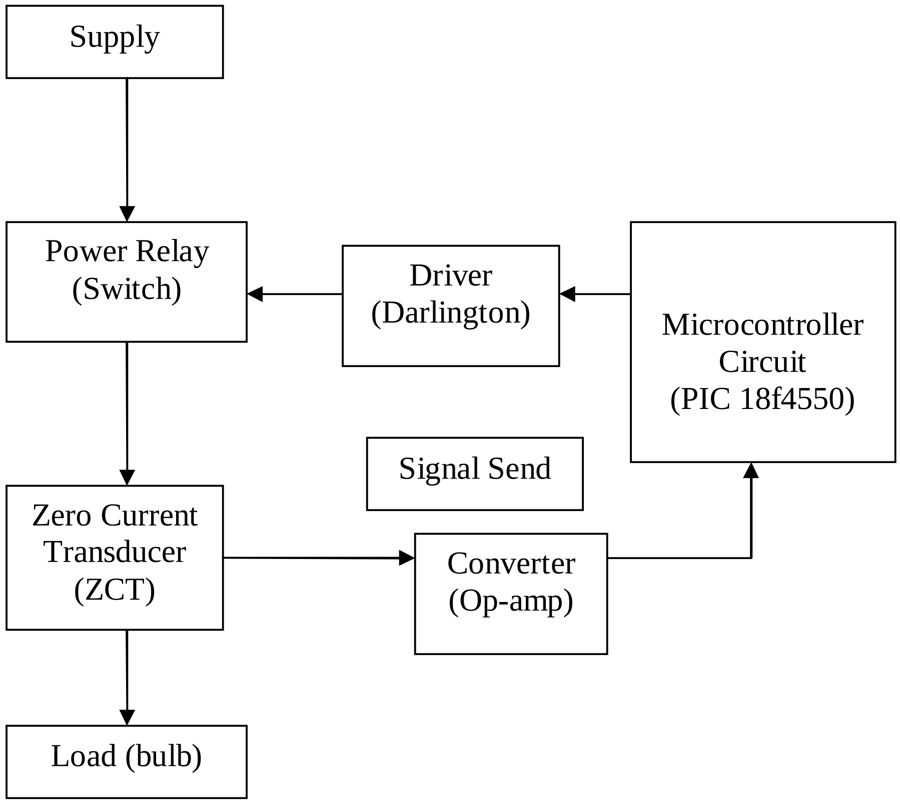

Figure 3.17: flowchart of ARELCB

3.7 Summary

Understanding each components concepts and functions has made the development process easier by make some research. Based on this new circuit, more efficient system has been developed by study the lack of older system and the function of device.

CHAPTER 4

CONTROL ELEMENT CIRCUIT

4.1 Introduction

Control element circuit consists of some components that work as a brain in overall ARELCB circuit. This circuit use to make a program consist timer or counter, command to relay and LCD, and use to process the input signal. The components in this circuit are microcontroller PIC18f4550 and crystal oscillator. In many project out there, it consist more than used in this project where they use some capacitors and resistors. However, these component might be skip because want to simply the circuit.

4.2 Microcontroller (PIC 18f4550)

PIC18f4550 is a programmable microcontroller with 32Kbytes of flash program memory and 2kbytes of general purpose SRAM. It has 13 A/D inputs and 18 general purpose I/O ports. PIC18F4550 has a range of features that can significantly reduce power consumption during operation. Key items include:

i) Alternate Run Modes: By clocking the controller from the Timer1 source or the internal oscillator block, power consumption during code execution can be reduced by as much as 90%.

ii) Multiple Idle Modes: The controller can also run with its CPU core disabled but the peripherals still active. In these states, power consumption can be reduced even further, to as little as 4% of normal operation requirements.

iii) On-the-Fly Mode Switching: The power-managed modes are invoked by user code during operation, allowing the user to incorporate power-saving ideas into their application's software design.

iv) Low Consumption in Key Modules: The power requirements for both Timer1 and the Watchdog.

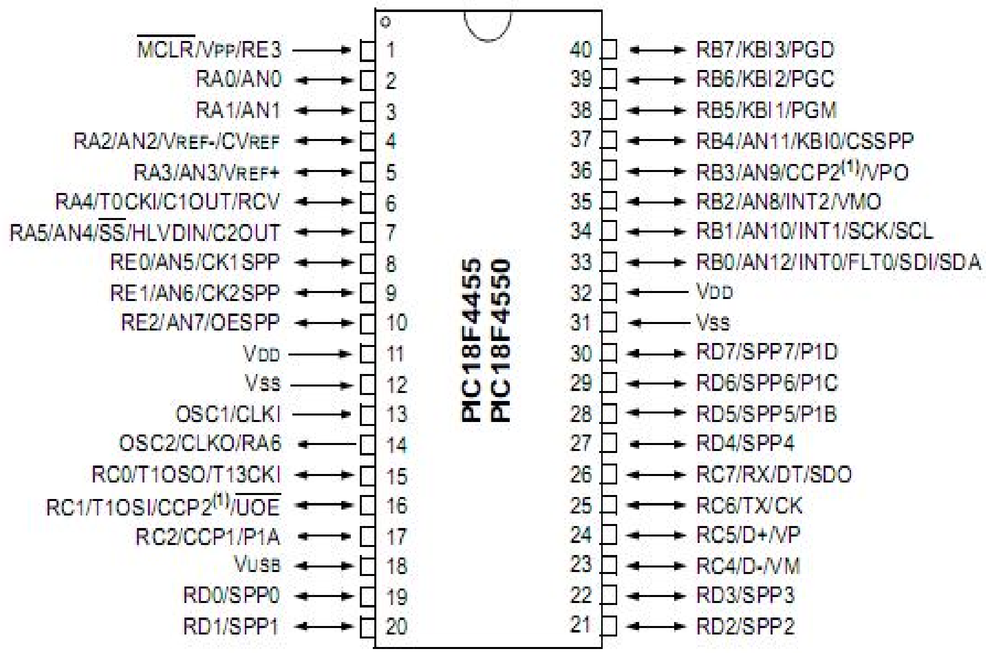

Figure 4.1: PIC18F4550

4.2.1 Other Special Features

This microcontroller also has features below;

i) Memory Endurance
ii) Self-Programmability
iii) Extended Instruction Set
iv) Enhanced CCP Module
v) Enhanced Addressable USART
vi) 10 Bit A/D Converter
vii) Dedicated ICD/ICSP Port

Devices in the PIC18F2455/2550/4455/4550 family are available in 28-pin and 40/44-pin packages. The devices are differentiated from each other in six ways:

i) Flash program memory (24 Kbytes for PIC18FX455 devices, 32 Kbytes for PIC18FX550).

ii) A/D channels (10 for 28-pin devices, 13 for 40/44-pin devices).

iii) I/O ports (3 bidirectional ports and 1 input only port on 28-pin devices, 5 bidirectional ports on 40/44-pin devices).

iv) CCP and Enhanced CCP implementation (28-pin devices have two standard CCP modules, 40/44-pin devices have one standard CCP module and one ECCP module).

v) Streaming Parallel Port (present only on 40/44-pin devices).

4.2.2 PIC18f4550 I/O Pin Description (used only)

Table 4.1: PIC18f4550 pin used detail

Pin Name	Pin No.	Description
MCLR/VPP/RE3 MCLR VPP RE3	1	Master Clear (input) or programming voltage (input). Master Clear (Reset) input. This pin is an active-low Reset to the device. Programming voltage input. Digital input.
OSC1/CLK OSC1 CLKI	9	Oscillator crystal or external clock input. Oscillator crystal input or external clock source input. External clock source input. Always associated with pin function OSC1. (See OSC2/CLKO pin.)

OSC2/CLKO/RA 6 OSC2 CLKO RA6	10	Oscillator crystal or clock output. Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. In select modes, OSC2 pin outputs CLKO which has 1/4 the Frequency of OSC1 and denotes the instruction cycle rate. General purpose I/O pin.
 RA0/AN0 RA0 AN0 RA1/AN1 RA1 AN1 RA2/AN2/VREF- /CVREF RA2 AN2 VREF- CVREF RA3/AN3/VREF + RA3 AN3 VREF+ RA4/T0CKI/C1O UT/RCV RA4 T0CKI C1OUT RCV RA5/AN4/SS/ HLVDIN/C2OUT RA5 AN4 SS HLVDIN C2OUT RA6	 2 3 4 5 6 7 _	PORTA is a bidirectional I/O port. Digital I/O. Analog input 0. Digital I/O. Analog input 1. Digital I/O. Analog input 2. A/D reference voltage (low) input. Analog comparator reference output. Digital I/O. Analog input 3. A/D reference voltage (high) input. Digital I/O. Timer0 external clock input. Comparator 1 output. External USB transceiver RCV input. Digital I/O. Analog input 4. SPI slave select input. High/Low-Voltage Detect input. Comparator 2 output. See the OSC2/CLKO/RA6 pin.
  RB0/AN12/INT0/ FLT0/ SDI/SDA RB0	 21	PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs. Digital I/O.

AN12		Analog input 12.
INT0		External interrupt 0.
FLT0		PWM Fault input (CCP1 module).
SDI		SPI data in.
SDA		I2C™ data I/O.
RB1/AN10/INT1/ SCK/ SCL	22	
RB1		Digital I/O.
AN10		Analog input 10.
INT1		External interrupt 1.
SCK		Synchronous serial clock input/output for SPI mode.
SCL		Synchronous serial clock input/output for I 2C mode.
RB2/AN8/INT2/ VMO	23	
RB2		Digital I/O.
AN8		Analog input 8.
INT2		External interrupt 2.
VMO		External USB transceiver VMO output.
RB3/AN9/CCP2/ VPO	24	
RB3		Digital I/O.
AN9		Analog input 9.
CCP2(1)		Capture 2 input/Compare 2 output/PWM 2 output.
VPO		External USB transceiver VPO output.
RB4/AN11/KBI0	25	
RB4		Digital I/O.
AN11		Analog input 11.
KBI0		Interrupt-on-change pin.
RB5/KBI1/PGM	26	
RB5		Digital I/O.
KBI1		Interrupt-on-change pin.
PGM		Low-Voltage ICSP™ Programming enable pin.
RB6/KBI2/PGC	27	
RB6		Digital I/O.
KBI2		Interrupt-on-change pin.
PGC		In-Circuit Debugger and ICSP programming clock pin.
RB7/KBI3/PGD	28	
RB7		Digital I/O.
KBI3		Interrupt-on-change pin.
PGD		In-Circuit Debugger and ICSP programming data pin.

4.3 Crystal Oscillator

A crystal oscillator is an electronic circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wristwatches), to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal. The suitable crystal for this project considered is 20 MHz.

Figure 4.2: Crystal oscillator

4.4 Hardware Design

In many PIC circuit, there are consist of PIC, crystal oscillator, reset button, capacitors and resistors. But after some testing done, PIC and its program run correctly without use the capacitors, resistor and reset button. So, in this circuit design, there are only use 20 MHz crystal accompanied PIC18f4550 to become complete for control element circuit and power supplied 5V come from 5V regulated circuit. This is because, reduce the component will reduce the space and easier to troubleshoot if any error happen.

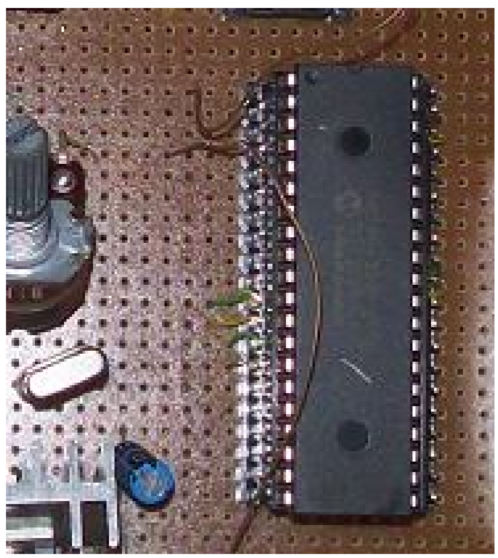

Figure 4.3: Control circuit

4.5 Programming Flowchart

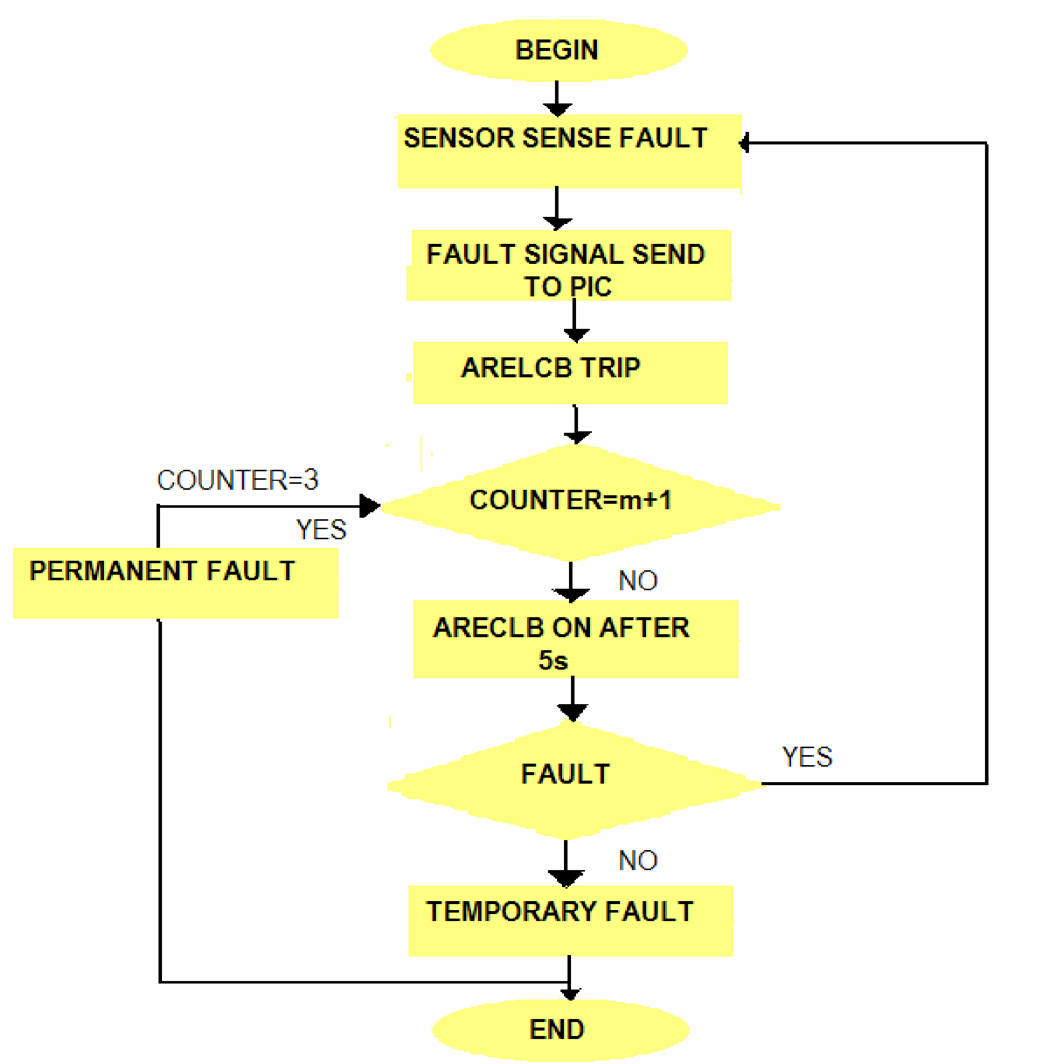

Figure 4.4: ARELCB programming flowchart

Based on Figure 4.4 above, programmed begin with sensor (Zero Current Transducer) sense fault from power line. If there have earth leakage current induce, ZCT will sense it to microcontroller (PIC18f4550) and microcontroller will give the output or trip order to relay to cut the power line. Then, PIC will make count in 3 counting if there has any signal from ZCT. If yes, it will decide as permanent fault based on fact, lightning will not happen in 3 second. But if there is no signal in that counting, ARELCB will turn on back the power line to normal condition after 5 second start from the count. For this condition, PIC will recognize it as temporary fault and displayed by liquid crystal display (LCD). The system will loop when it show the temporary fault.

4.6 Programming Detail

For starting programming PIC18f4550, Microcode Studio-PIC BASIC PRO chosen because this is simpler software and user friendly. Firstly, the oscillator must be defined according the crystal used in circuit. So, it set 20. Then, LCD port and bit defined followed by define the analog-digital converter (ADC). In ADC, we must consider in define the number of bits, the clock source and the sampling time in microseconds. After that, the data to send to PIC must be identified by use VAR command. So, three data is identified to give some command in program which are VOLT, M and N. Volt use to set the program to operate at greater than $51 byte (1 volt in actual value). M and N use to make counter in program. Then, the output and input pin of PIC define by using command TRISA and TRISB mean port A and B used. So, 0 is set for the output, and 1 use as input.

Begin of the main part of program, IF use to make choice or comparison at two probability. When program start, M and N are 0, not make any count. But, if there are VOLT detected greater than $51 byte, port B1 and port B2 will high and at same time, M will start count. If M count to 3 and there are still detecting VOLT, LCD will display SHORTCIRCUIT which mean it is permanent fault. But if counter less than 3, and there are no VOLT detected, it will low port B1 and PORT B2 which are for relay and LED indicator. At same time, counter N will count in 5 counts. If N greater than 5 it will go to M count which mean at begin of program.

4.7 Summary

Using microcontroller has made the system more flexible in time, function and has ability to be upgraded soon by changes in programming system. Besides, it has reduces the cost and space of control circuit, compared to the use of fully mechanical controller components like portable timer and portable counter. The programming for PIC18f4550 also is easier than other microcontroller because it simple, easy to understand and simple.

CHAPTER 5

RESULTS & DISCUSSIONS

5.1 Introduction

This chapter describes about the results and discussions for the whole development of Auto Re-Closer Earth Leakage Circuit Breaker (AR-ELCB) project process. The result that will be discussed in this chapter is for the measurement of Zero Current Transformer (ZCT), the calculation to built converter circuit and the result for the whole AR-ELCB systems. The calculation involve in this chapter is depends on the result of measurement of ZCT. It is due to the ZCT function as the sensor in the system, only system with the great sensor can achieve the objectives. There is no meaning if the sensor of this system failed to operate. Every discussion stated in this chapter also is for the whole system problems, the priority must be to overcome the problems of this AR-ELCB system.

5.2 Measurement of current induce in ZCT

The objectives of measurement ZCT is to get the value of output current from the winding wire of the ZCT, the induced current will be absorbed by the core then is transferred to the winding and the currents will flow through the winding. The priority must be taken care for the current magnitude, which one is positive and negative. This is very important while in designing the current controlled voltage source.

The 240Vac/6A single phase motor (Figure 5.1) and 240Vac/1A bulb (Figure 5.2) have been used as the load, the significant of used the motor is it drew high current for starting, this situation theoretically produced the spark at the beginning but after that the condition will back to normal, this condition could be assume as lightning occurred, the concept is same. But the most important thing is from this experiment is to gain the lowest value of currents that could be detected by ZCT to produce the output current.

To measure the ZCT, only live line supply is passed through ZCT hole, where the neutral line will not passed though it, so the flux produce by both line will not overlapped to each other and the ZCT theoretically should sense the flux and produce output current at the starting motor.

Figure 5.1: 6A motor


Figure 5.2: 1A Bulb

Table 5.1: ZCT current induce

NO\LOAD	BULB(1A) (mA)	MOTOR(6A) (mA)
1	25.30	85.3
2	17.03	143.3
3	26.02	49.05
4	28.67	219.30
5	19.84	65.03
6	27.30	217.91
7	27.50	121.60
8	31.08	136.60
9	22.00	96.20
10	25.55	273.24

Based on the table, show the different between current induce in ZCT when using 6A motor and 1A bulb. The reading taken at first spike of starting motor and bulb, so there are highest measurements. This is because motor need more power at starting time compare when it running. Data shows value from motor greater then value from the bulb. This is because the current for the motor greater (6A), so the coil will produce more electromagnetic field in ZCT. Then, the current induce is greater then bulb which using 1A. The experiments done to two different loads to show the relation supply current and induce current. So, the supply current is directly proportional to the current induce.

5.3 Measurement of Op-Amp Voltage Output

Voltage output from op-amp use as input voltage signal to PIC18f4550. This voltage must be variable because we can program the PIC to operate at certain voltage value. So, variable resistor used to control output voltage from op-amp show in Figure 5.3.

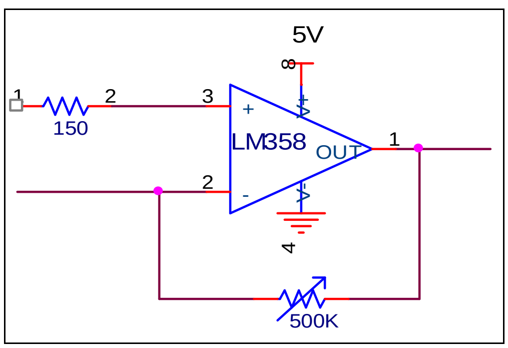

Figure 5.3: Op-amp

Input op-amp is current from ZCT convert to voltage through the 150ohm resistor and amplified by LM358 accompanied by 500k variable resistor. Motor run and reading taken after it show a constant reading. It cannot take reading at higher reading because when motor start the current will spike at higher current. Table below shows the voltage output from op-amp.

Table 5.5: Output voltage from op-amp

No	Resistance(Ω)	Voltage(V)
1	1k	0.78
2	50k	1.19
3	150k	1.35
4	200k	1.50
5	250k	1.73
6	300k	1.76
7	350k	1.79
8	400k	1.80
9	450k	1.82
10	500k	1.82

Actually voltage output of op-amp can calculate using the theory formula based on resistance and the input current. Although microcontroller needs whatever value of input voltage, this experiment must be done to show the relation between current and voltage through the op-amp. Actually op-amp used to amplify the voltage after the resistor to make it clear to measure in greater value. This is important because the greater voltage produce is more stable and easy to microcontroller detect the input signal. This can make the circuit operate more stable and more persistence.

5.4 Arrangement of fault model

Fault model is very important in this project to demo this circuit to test the function and efficient of the circuit. So, the model is design using also with a 6A motor to produce same current induce like when we test the ZCT. So, one of the wire of the motor place into the ZCT while another place outside, this is because this step will exist the imbalance current flow in ZCT. But both two wire of load (lamp) will placed into ZCT to work as indicator to the system. For temporary fault, the load line will on all the time to on the circuit system while the motor power supply will on and off at one second to act like the lightning which come in only some second or less than one second. So, the lamp will off when the motor on and otherwise.

For the permanent fault model, the arrangement stills same but has a little different at time period of motor turned on. Motor will turn on for more than five second and lamp will turn off. After the motor turn off, lamp will not turn on because system considers it is permanent fault. This is because permanent fault occur in a long period unlike the temporary fault which is in about one second.

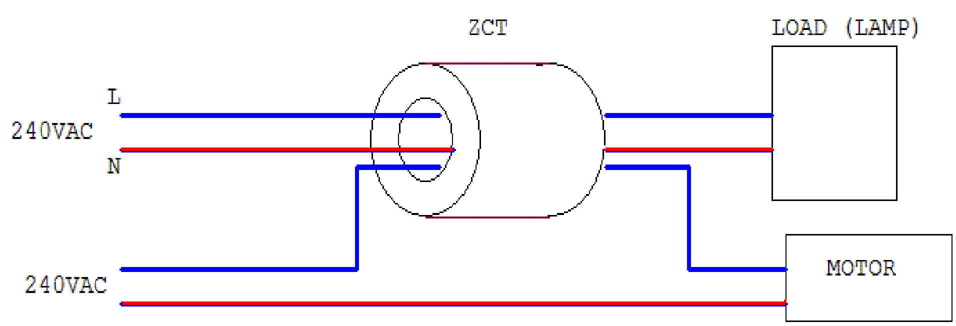

Figure 5.4: Fault model arrangement device

5.5 Project Results

Based on testing and experiment, the results of this project are show as below:

i. PIC18f4550 microcontroller can act like commanded in the programming.
ii. The AR-ELCB successfully built, operating like command and can differentiate between permanent and temporary fault.
iii. AR-ELCB holds the circuit for 3 second and followed by red LED light if the lightning or current leakages occur and retract to the normal condition after that.
iv. AR-ELCB permanently closed the circuit if the circuit detects the leakage continuously in 5 counts and the red LED light, the circuit will only back to normal condition and the red LED will off after the user clear the fault manually.
v. LCD works follow as the types of fault exist, temporary and permanent.
vi. Zero current transformer produce enough current signal when it tested using the motor.

5.6 Discussions

According on this project, the discussions that have been stated are:

i. Datasheet about former ELCB is very lack of information. So the process of measuring the ZCT does not have the guideline. Besides, the knowledge about this component is very limited.

ii. Analysis the ZCT is pretty hard due to device shortage. The device like power analyzer should be added in the laboratory and the student must be introducing to this type of device from year first in the University yet.

iii. Lack of references for his project is the development so everything that new must be creatively thinks how to solve although a little problem. The combination from own readings and the analog electronic knowledge help a lot.

5.7 Summary

According on the results and discussions in this project, there are some important things that could be consider to complete the whole ARELCB system, it is the sensitivity of this system, which shows through the experiment of the Zero Current Transducer (ZCT), the sensitivity of the product or device depends on this result, it is due to the only device that can control the sensitivity is the ZCT and converter circuit.

CHAPTER 6

CONCLUSIONS & SUGGESTIONS

6.1 Conclusions

All of objectives of the development of Auto Re-closer Earth Leakage Circuit Breaker were successfully work. In the designing the Auto Re-closer Earth Leakage Circuit Breaker it need the combination of analog electronics knowledge, auto-tronics knowledge, Microprocessor knowledge, power electronic knowledge and individual self skilled method to create the new circuit, it is due to there is no AR-ELCB circuit in the internet for comparison and as references, it is the new product. The use of LM7808 and LM7805 voltage regulators have increase the efficiency and reduce the cost of the system compared to by using the transformer less circuit. Using the Heavy power relay compared to solid state relay have reduce the cost and increase the reliability of the device where the device is not easy to burn out if wrong polarity installed to this device. So for the learning process it is better choice to use the heavy power relay because it is more to electromechanical system. The PIC18f4550 is a microcontroller as a brain has made the system more reliable for modern technology and the timer and delay for the system can be adjusted by changing the programming command. It also has improved the ability of Auto Re-closer Earth Leakage Circuit Breaker (AR-ELCB). Then the system also can act accurately besides can be updated by reprogram the IC. The successful of this AR-ELCB system has made the circuit can differentiate between permanent and temporary fault and acting differently between each type of fault.

6.2 Suggestions

There are some suggestions after the process for improvement AR-ELCB to the next development in future:

i. Replace the entire huge component like power relay and PIC to smaller component but in same function and rating. This can make ARELCB smaller and it relevant to use and can be commercialized.

ii. For design the circuit, choosing of suitable device is important, the priority must be for the current rating and the device endurance.

iii. Analyze the Zero Current Transformer (ZCT) before buy the device for converter circuit. Make sure use power analyzer for analysis ZCT, the thing that must be measured is input and output of ZCT. Try to get the datasheet of ZCT from the device supplier.

iv. For the next project student must study the former ELCB detailed and make sure to understand for the system process before make the new design for the new device.

v. Replace the bridge with 4 diode, array and connect it in the full wave rectifier connection, it will reduce the cost of bridge that is really expensive.

vi. Replace the R_L for current controlled voltage source with the variable resistor where the variable resistor will make the rating for unbalance current can be variable. So the variable AR-ELCB can be produce. Variable AR-ELCB is more productive where the rating of unbalance current can be adjusted by consumer themselves or by industry to fulfill their demand.

6.3 Costing and Commercialization

With take the total cost of the development of Auto Re-closer Earth Leakage Circuit Breaker, RM176.50 used to buy the components and some more cost. But the actual price of the whole AR-ELCB circuit is only RM 135.10. It is due to the replacing of component in the development process, besides there were the components that do not function and need to be change while in circuit building process. The cost stated above is for the electronic and electric components that used and involve in this project. The cost for the AR-ELCB can be reduced by following the suggestion stated in the suggestion section and buy the components in bulk.

By the way, this project can be commercialize by built the new AR-ELCB that follow the feature that have been recommended in the suggestion section, it is due to the cost of the recommended new AR-ELCB is more cheaper than this new invention one. The estimated cost should be around RM 120.00 only without buy components in bulk way. Table 6.1 below shows the total estimate price for all components.

ARELCB has the higher commercialize potency because it can solve the existence ELCB problems.

Table 6.1: Total estimate price for ARELCB

No	Component	Specification	Price Estimate / unit	Quantity	Price Estimate
1	Transformer	240VAC/15VAC	RM30.00	1	RM30.00
2	DPNO power relay	240V/12VDC(coil)	RM45.00	1	RM45.00
3	Bridge rectifier		RM2.00	1	RM2.00
4	Voltage regulator	LM7812	RM1.00	1	RM1.00
5	Voltage regulator	LM7805	RM1.00	1	RM1.00
6	Liquid Crystal		RM25.00	1	RM25.00

	display				
7	Microcontroller	PIC18F4550	RM20.00	1	RM20.00
8	Darlington diode	BD361	RM2.00	1	RM2.00
9	Op-amp	LM358	RM3.00	1	RM3.00
10	ZCT		RM3.00	1	RM3.00
11	Relay	5VDC	RM2.00	1	RM2.00
12	Resistor	100Ω, 10Ω	RM0.10	3	RM0.30
13	Capacitor	100µF, 10µF	RM0.20	4	RM0.80
Total Price Estimate					RM135.10

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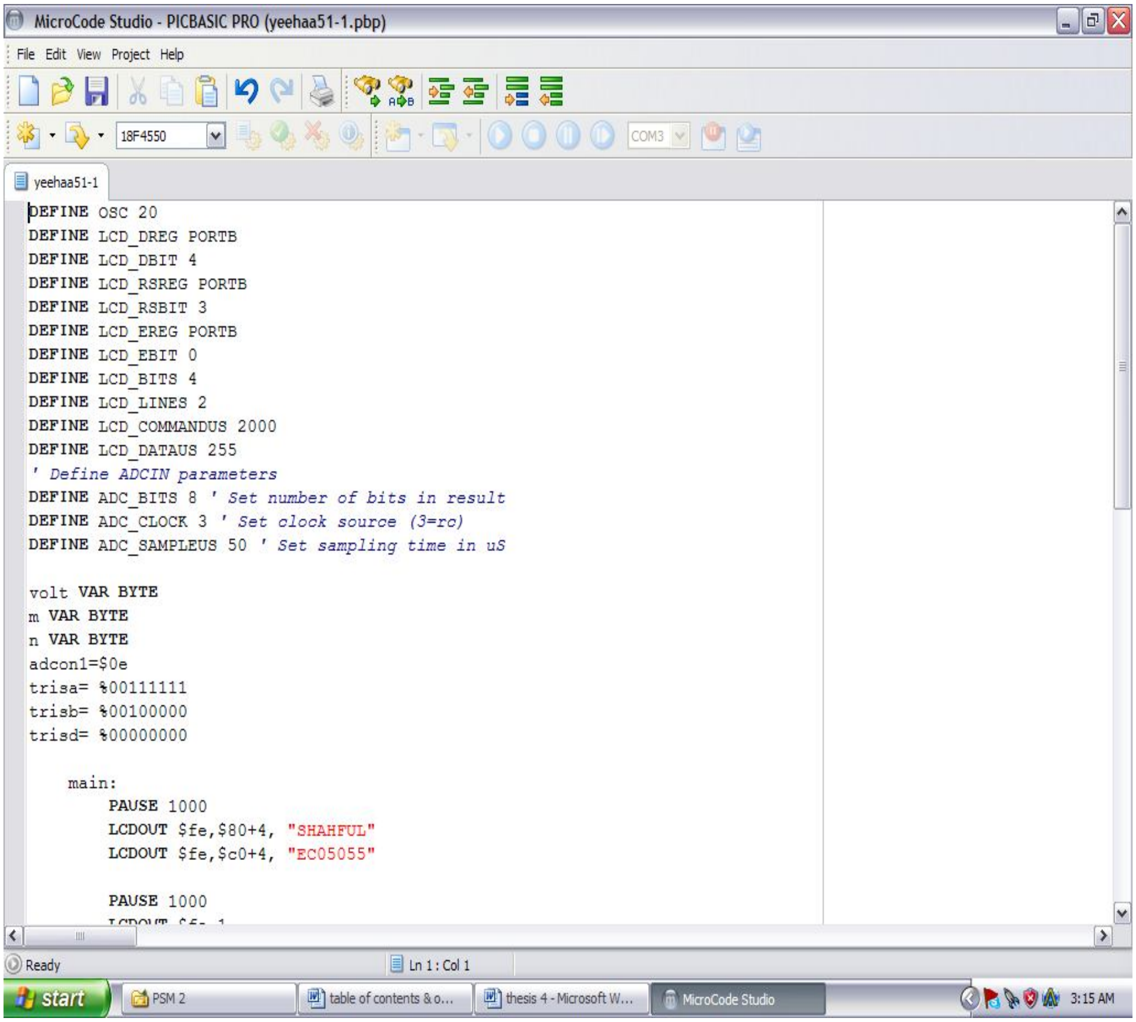
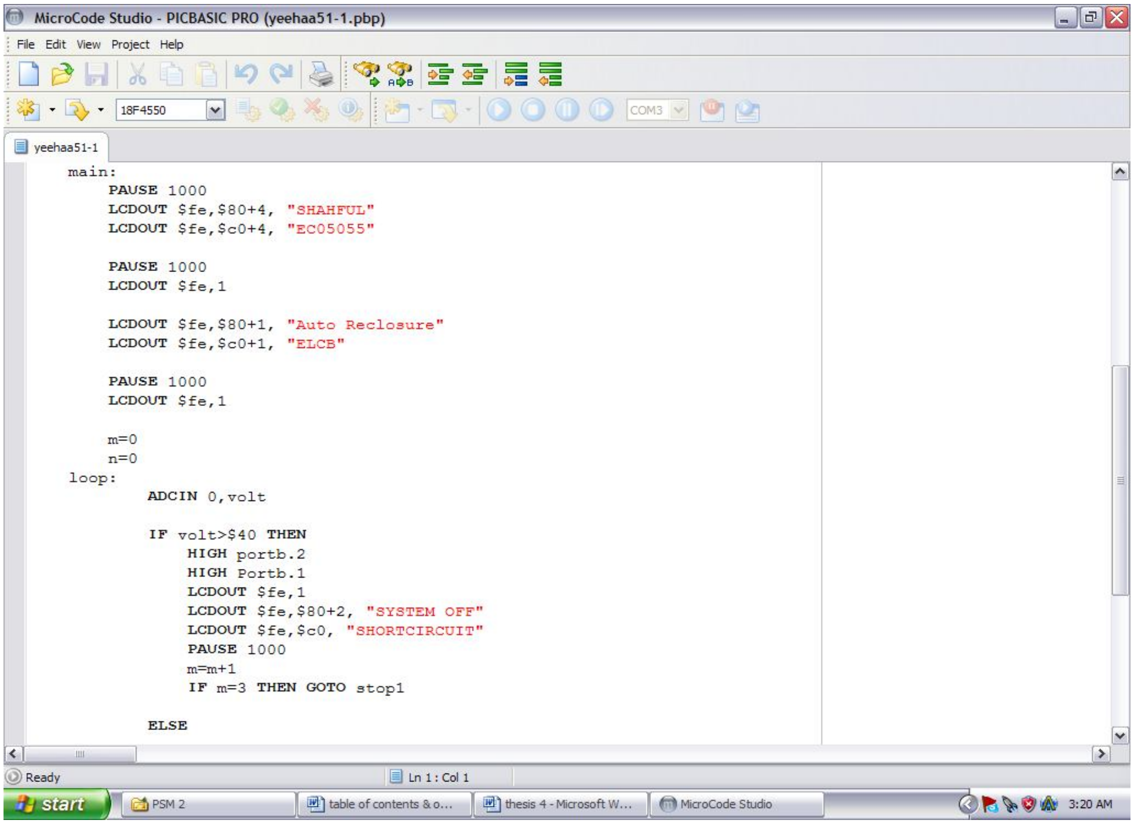
APPENDIX A

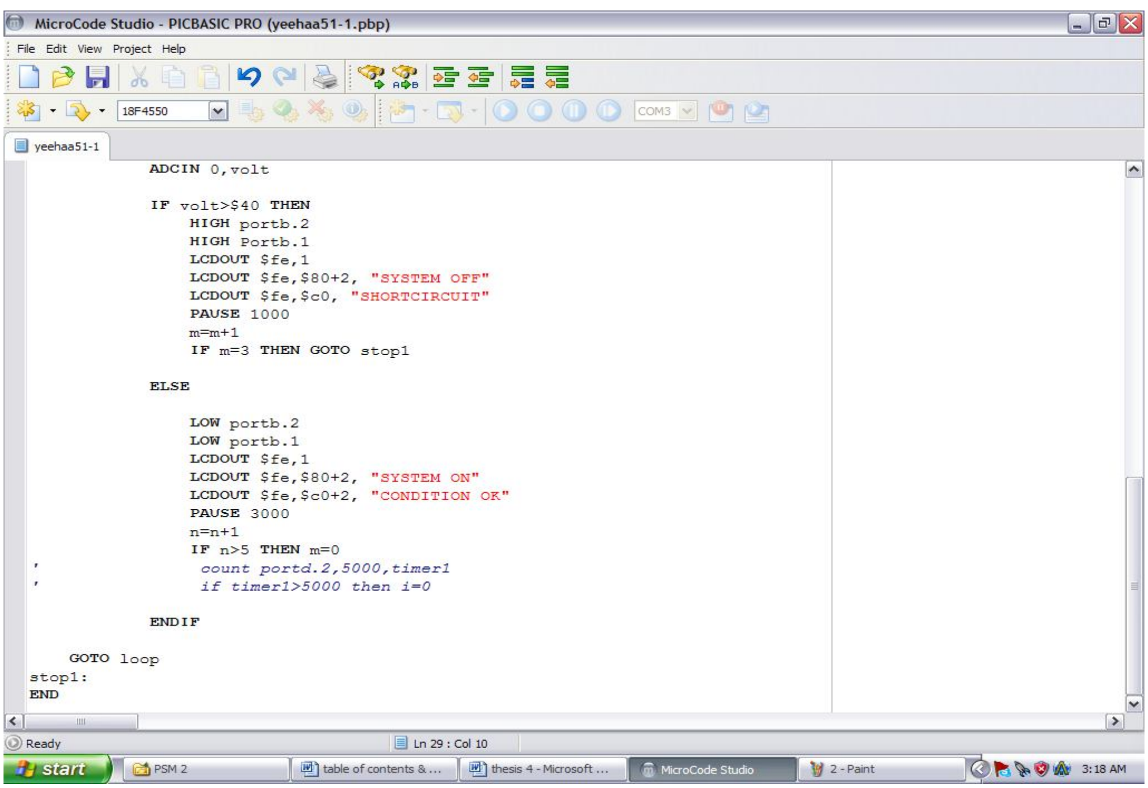
AR-ELCB Programming

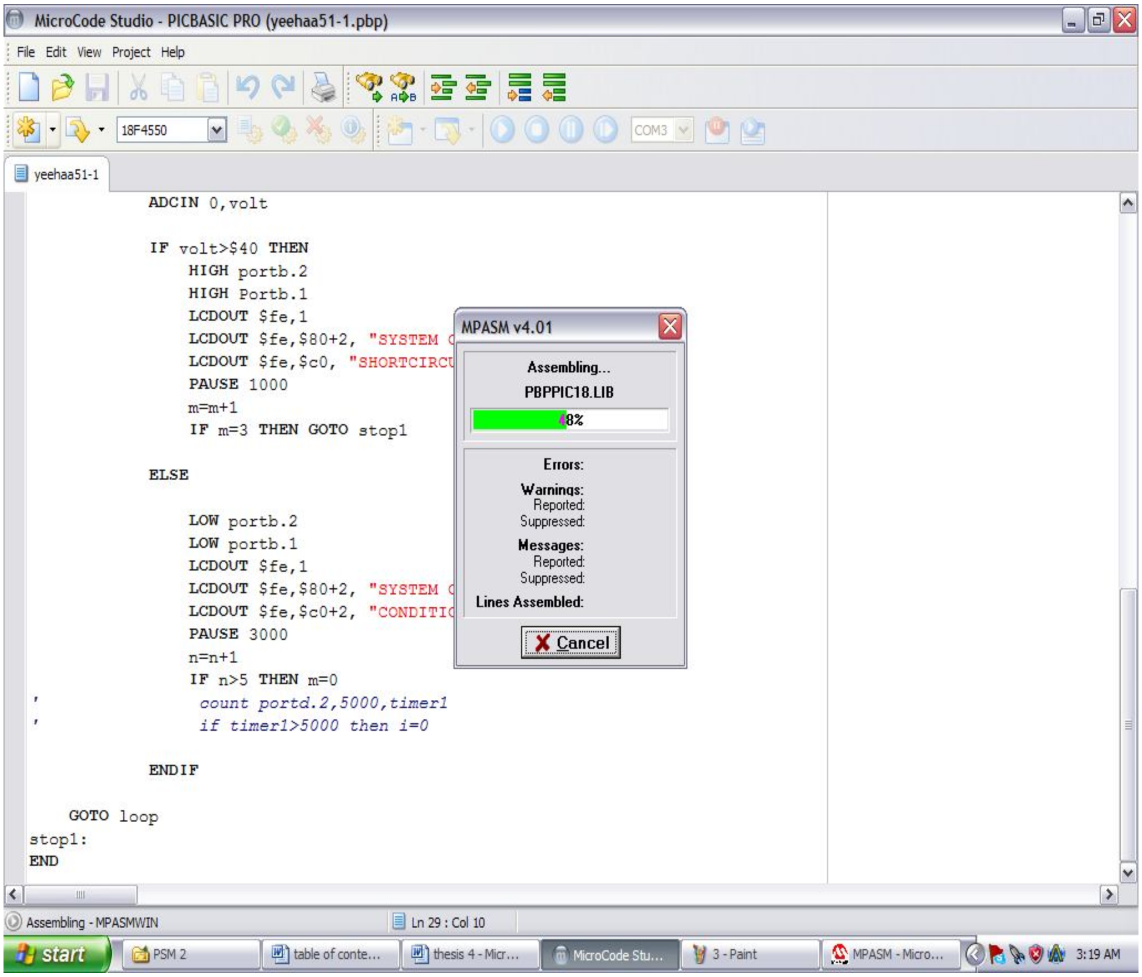
AUTO RE-CLOSER EARTH LEAKAGE CIRCUIT BREAKER (AR-ELCB) PROGRAMMING USING PIC18F4550 MICROCONTROLLER



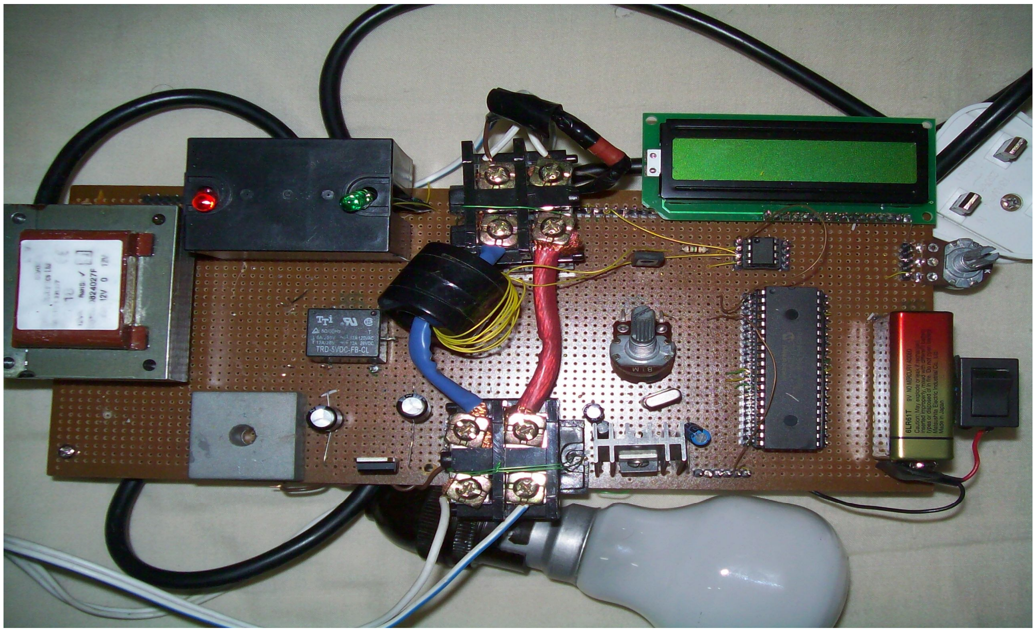

```
DEFINE OSC 20
DEFINE LCD_DREG PORTB
DEFINE LCD_DBIT 4
DEFINE LCD_RSREG PORTB
DEFINE LCD_RSBIT 3
DEFINE LCD_EREG PORTB
DEFINE LCD_EBIT 0
DEFINE LCD_BITS 4
DEFINE LCD_LINES 2
DEFINE LCD_COMMANDUS 2000
DEFINE LCD_DATAUS 255
' Define ADCIN parameters
DEFINE ADC_BITS 8 ' Set number of bits in result
DEFINE ADC_CLOCK 3 ' Set clock source (3=rc)
DEFINE ADC_SAMPLEUS 50 ' Set sampling time in uS

volt VAR BYTE
m VAR BYTE
n VAR BYTE
adcon1=$0e
trisa= %00111111
trisb= %00100000
trisd= %00000000

    main:
        PAUSE 1000
        LCDOUT $fe,$80+4, "SHAHFUL"
        LCDOUT $fe,$c0+4, "EC05055"

        PAUSE 1000
```

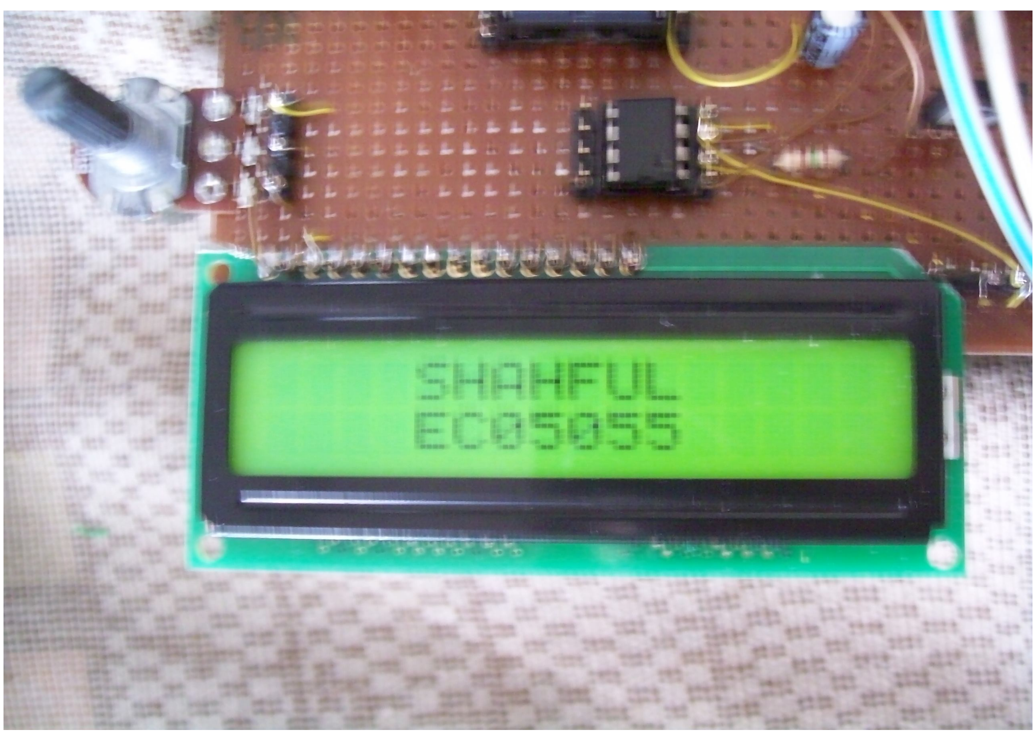

MicroCode Studio - PICBASIC PRO (yeehaa51-1.pbp)
File Edit View Project Help
18F4550
COM3
yeehaa51-1
main:
PAUSE 1000
LCDOUT $fe,$80+4, "SHAHFUL"
LCDOUT $fe,$c0+4, "EC05055"
PAUSE 1000
LCDOUT $fe,1
LCDOUT $fe,$80+1, "Auto Reclosure"
LCDOUT $fe,$c0+1, "ELCB"
PAUSE 1000
LCDOUT $fe,1
m=0
n=0
loop:
ADCIN 0,volt
IF volt>$40 THEN
HIGH portb.2
HIGH Portb.1
LCDOUT $fe,1
LCDOUT $fe,$80+2, "SYSTEM OFF"
LCDOUT $fe,$c0, "SHORTCIRCUIT"
PAUSE 1000
m=m+1
IF m=3 THEN GOTO stop1
ELSE
Ready
Ln 1 : Col 1
start
PSM 2
table of contents & o...
thesis 4 - Microsoft W...
MicroCode Studio
3:20 AM

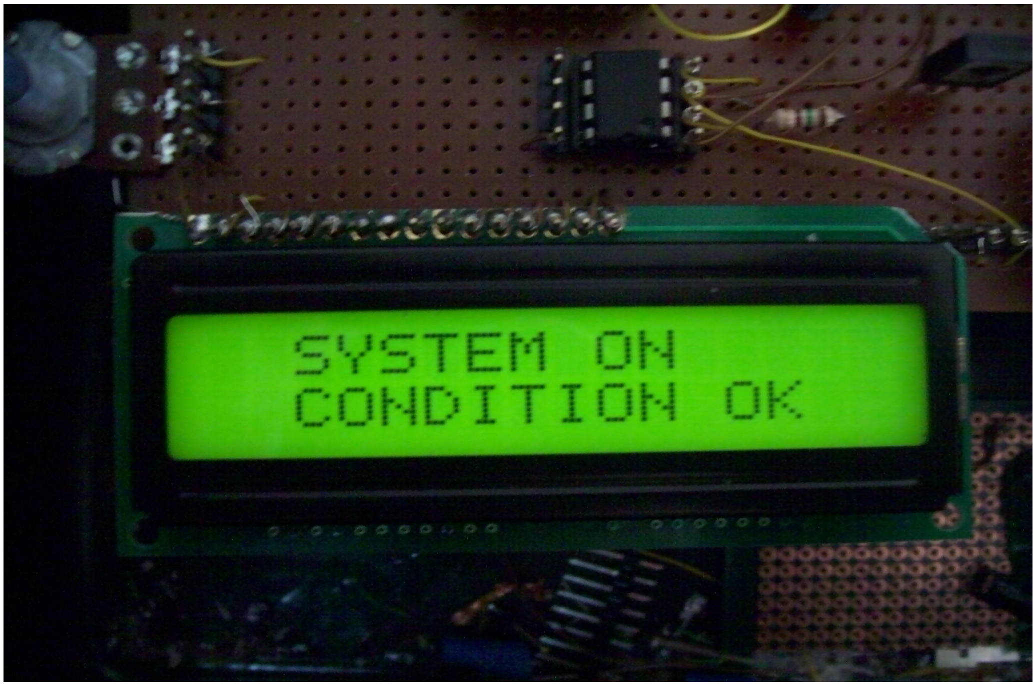

MicroCode Studio - PICBASIC PRO (yeehaa51-1.pbp)
File Edit View Project Help
18F4550
COM3
yeehaa51-1
ADCIN 0,volt
IF volt>$40 THEN
HIGH portb.2
HIGH Portb.1
LCDOUT $fe,1
LCDOUT $fe,$80+2, "SYSTEM OFF"
LCDOUT $fe,$c0, "SHORTCIRCUIT"
PAUSE 1000
m=m+1
IF m=3 THEN GOTO stop1
ELSE
LOW portb.2
LOW portb.1
LCDOUT $fe,1
LCDOUT $fe,$80+2, "SYSTEM ON"
LCDOUT $fe,$c0+2, "CONDITION OK"
PAUSE 3000
n=n+1
IF n>5 THEN m=0
' count portd.2,5000,timer1
' if timer1>5000 then i=0
ENDIF
GOTO loop
stop1:
END
Ready
Ln 29 : Col 10
start
PSM 2
table of contents & ...
thesis 4 - Microsoft ...
MicroCode Studio
2 - Paint
3:18 AM

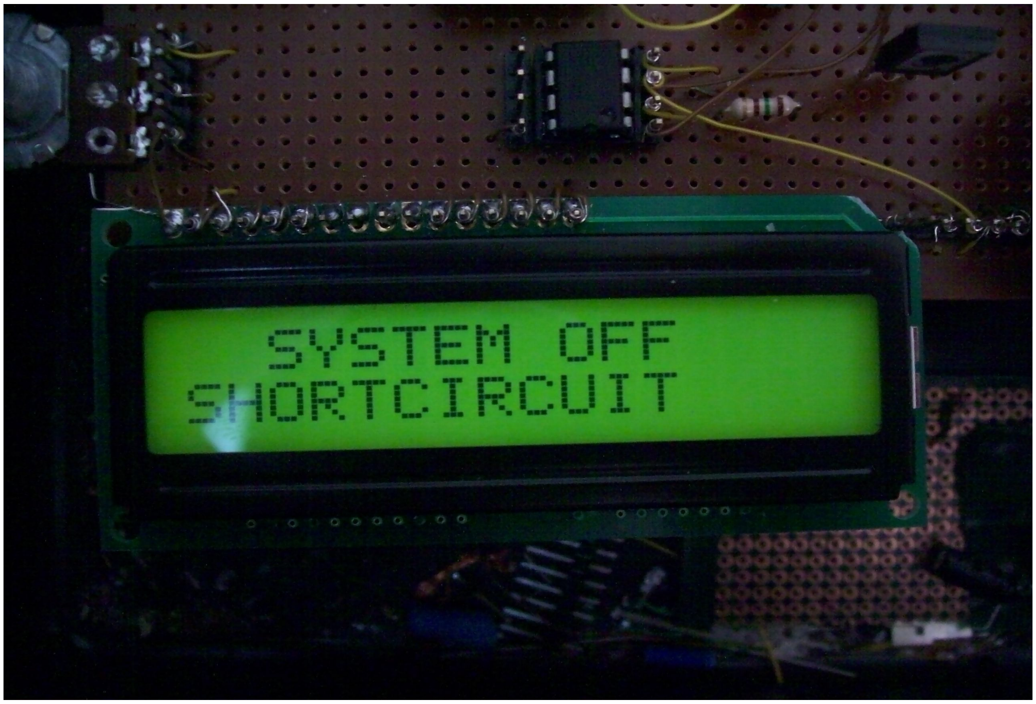

MicroCode Studio - PICBASIC PRO (yeehaa51-1.pbp)
File Edit View Project Help
18F4550
COM3
yeehaa51-1
ADCIN 0,volt
IF volt>$40 THEN
HIGH portb.2
HIGH Portb.1
LCDOUT $fe,1
LCDOUT $fe,$80+2, "SYSTEM
LCDOUT $fe,$c0, "SHORTCIRCU
PAUSE 1000
m=m+1
IF m=3 THEN GOTO stop1
ELSE
LOW portb.2
LOW portb.1
LCDOUT $fe,1
LCDOUT $fe,$80+2, "SYSTEM
LCDOUT $fe,$c0+2, "CONDITIO
PAUSE 3000
n=n+1
IF n>5 THEN m=0
' count portd.2,5000,timer1
' if timer1>5000 then i=0
ENDIF
GOTO loop
stop1:
END
MPASM v4.01
Assembling...
PBPPIC18.LIB
48%
Errors:
Warnings:
Reported:
Suppressed:
Messages:
Reported:
Suppressed:
Lines Assembled:
Cancel
Assembling - MPASMWIN
Ln 29 : Col 10
start
PSM 2
table of conte...
thesis 4 - Micr...
MicroCode Stu...
3 - Paint
MPASM - Micro...
3:19 AM

APPENDIX B
ARELCB hardware pictures




SHAHFUL
EC05055


SYSTEM ON
CONDITION OK


SYSTEM OFF
SHORTCIRCUIT

AUTHOR'S BIODATA

Shahful Bakhtiar Bin Shahiran was born on 14th August 1986 in Felda Sebertak, Triang, Pahang. He is 7th child of 10 siblings. He was completed his secondary studies in at Sekolah Menengah Sains tengku Abdullah, Raub, Pahang at 2003. Then he was further study in Science physics course at Melaka Matriculation College from 9 May 2004 until 14 April 2005. He is currently (2009) a Bachelor's student in the Electrical Engineering (Power System), faculty of Electrical and Electronics Engineering, University Malaysia Pahang. His research fields are power electronics and power system. He is a student member of the IEM of Malaysia and active in co-curriculum.