UNIVERSITY OF BRADFORD
MAKING KNOWLEDGE WORK™

engineering design + technology

SENSORS AND ACTUATORS_PAPER DESIGN COURSEWORK

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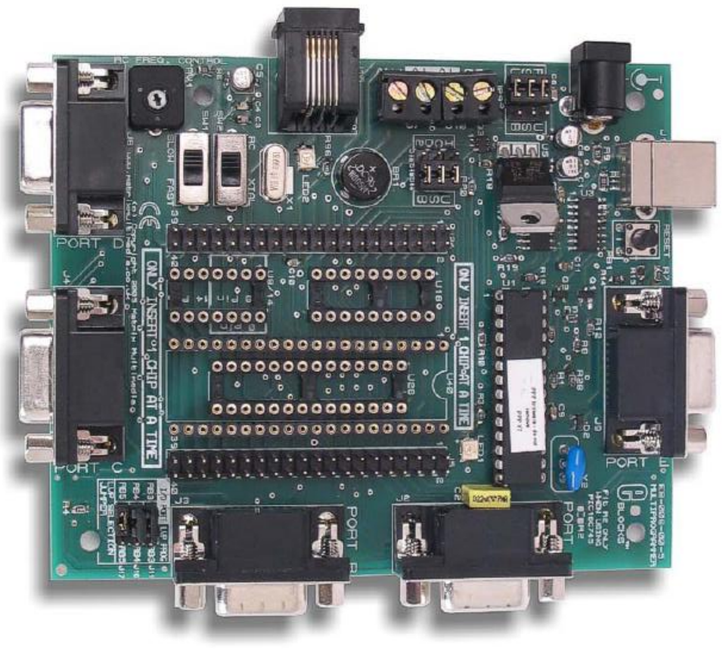

Supervised by Dr P Jiang

Burglar Alarm Project Report

K.NHUBU, A.MAZHINDU & S.CHIWESHE

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INTRODUCTION

- This Sensors and Actuators Paper design project is aimed at planning, designing and building a Burglar Alarm of a house.
- It uses PIC based microprocessor (PIC16F88) for driving a four channel security system.
- The main focused point of this project is activating alarm for different zones

AIM

- To design and implement the electronic control unit for a burglar alarm system, suitable for operation in a small office/home environment. The unit will be easy to operate, with one button arm/disarm, and visual and audio indicators of alarm status.
- Aims are to discover the different possibilities of enhancing home security and carry an extensive research of the existing options
- Capable of detecting and identifying area of intrusions

Source 1: http://www.all-about-the-home.co.uk

ALARM STRUCTURE

External Inputs
4 Zone Inputs

Control Unit
4 Continuously Monitored Zones
4 LED's – Status of each Zone
Arm / Disarm and Reset Switches
Alarm Status Indicators(s)

Alarm Outputs
Contacts for the connection of
1. External Buzzer
2. External Strobe

Figure 1: Alarm Structure

Source 2: http://www.all-about-the-home.co.uk

Hardware System Design

- The development board used for testing purposes is the version 3 PIC Micro Controller
- Two sensors and a buzzer used for building simple alarm system
- The system incorporates an LCD and a key pad
- PCB design produced for a workable alarm system with the given specifications and which can be easily modified

Software System Design

- Source boost IDE used for programming micro controller
- Program written for controlling hardware (sensor and buzzer) that includes keypad
- Software code gives option to change security PIN number
- Activation of different zones is enabled

Burglar Alarms Research

Most burglar alarm systems run from a fixed 12V power supply. This is also the standard operating supply voltage for usual subsystems such as any PIR Sensors, heat, pressure or magnetic sensors etc. A standard also exists for how input sensors operate. They normally use a normally closed (N.C.) loop for sensors, so that an alarm condition is signalled by a switch being opened within the sensor and cutting the circuit. This means that should a burglar cut the wires to a sensor, then the loop will be cut and an alarm signal is generated.
Most burglar alarms have the capability to monitor the input sensors separately, so that in the event of a burglary, it is known which sensors were and were not triggered so that the point of entry and extent of break in can be identified.

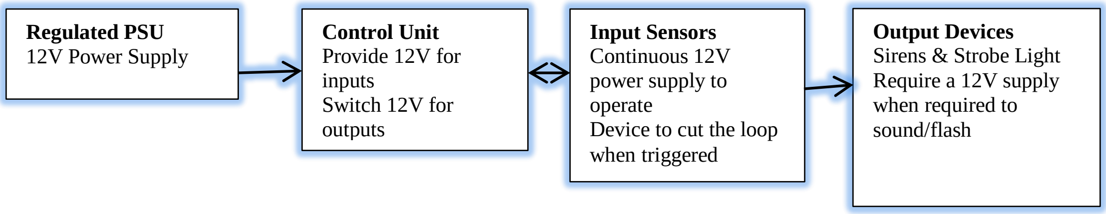


Figure 2: Pre-Data Diagram

Programming the PIC

A "version 3 PIC Micro Controller Development Board", is used to design. These boards enable to write a program for the device on a computer, test its operation using a software simulation and then finally program our creation onto a PIC 16F88 device. The chip can then be implanted in the circuit.
The development board have a set of switches and LEDs to test the operation of the program in hardware. Schematics are to be used as guidance on interfacing with this device in the circuit.
The program is written using a text editor such as Notepad. The file is saved and is compiled using an assembler/compiler program to convert to machine code. This is then downloaded to the development board.

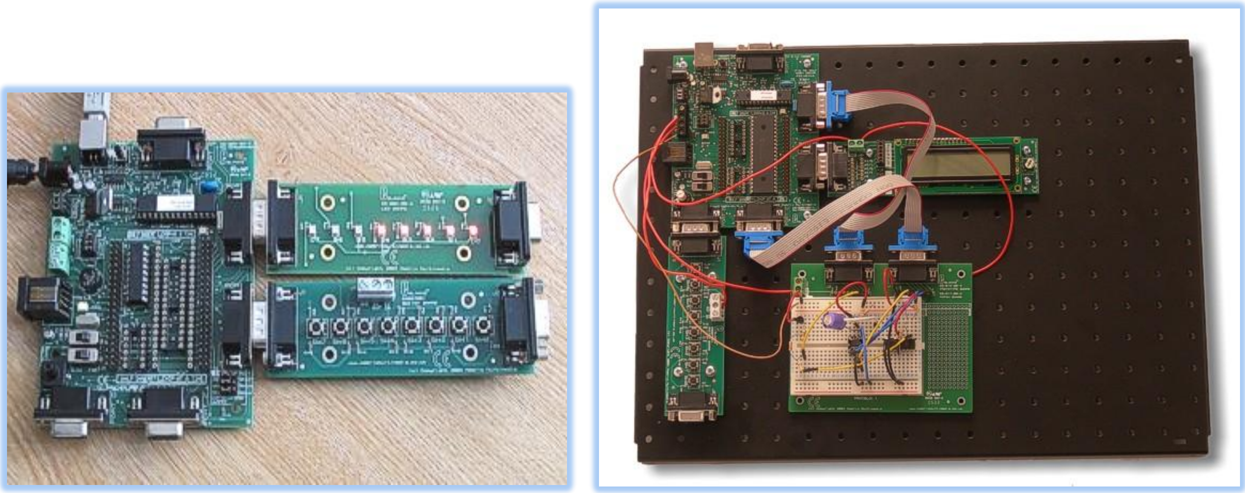


Figure 3: Multi Development Board PIC Controller

SPECIFICATION

Requirements

- Operating Voltage 12V Regulated Power Supply
- Input Zones- 4 individually-monitored Inputs
- Control Switches Arm / Disarm and Reset for Ease of use
- Indication when a zone has been tripped, preferably which was tripped first
- Alarm Output Switched 12V during alarm condition
- Be able to drive > 500mA output current
- Input Sampling Time > 20 Times each second
- Low Standby Current < 200 mA

POSSIBLE SOLUTIONS

As the PIC chip itself can be used to sample the zone inputs and to remember which input was tripped first? However using a PIC Controller will require knowledge in assembly language and on interfacing the chip with external components.

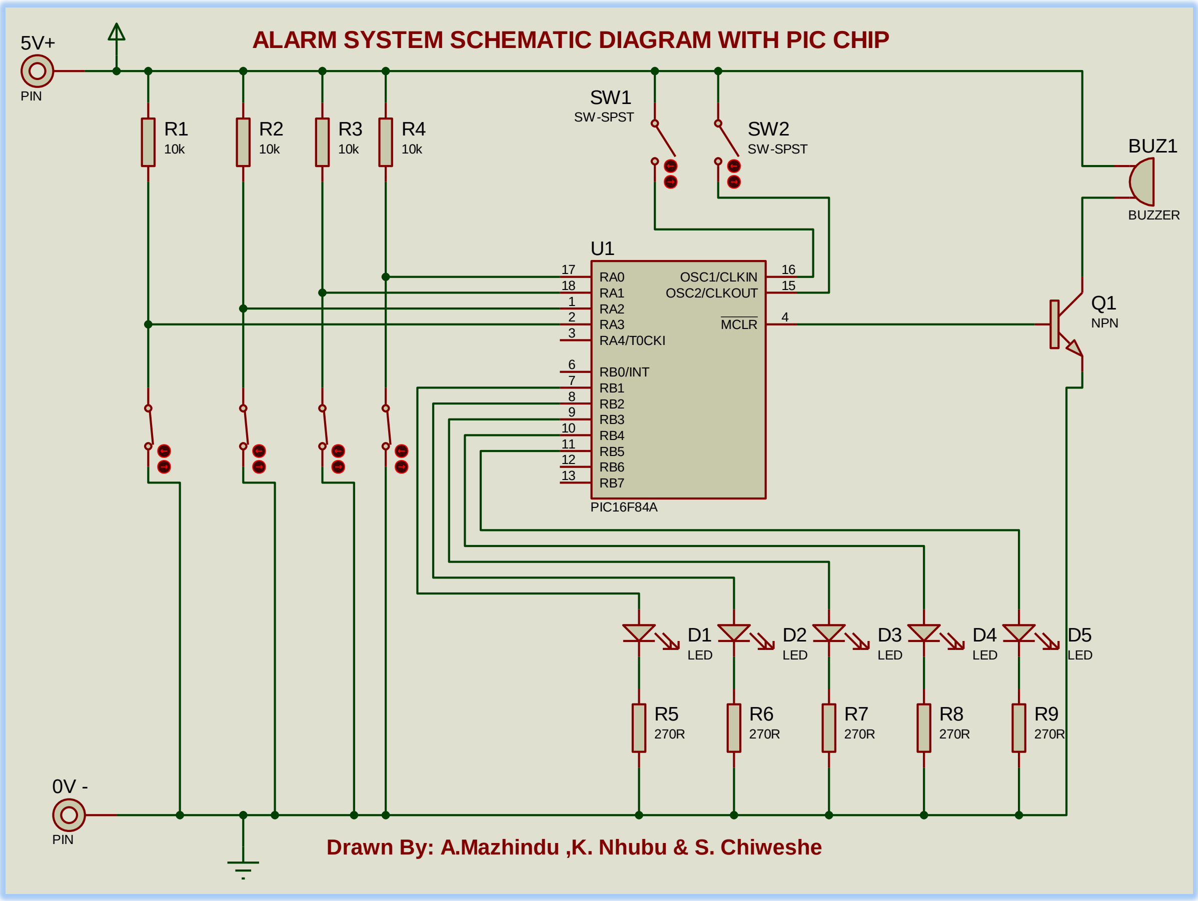


Figure 4: Alarm System Circuit Diagram with PIC Chip

Another solution is to provide the operation by using a series of logic gates to compare the state of the zone inputs against the status of an alarm / disarmed switch and make a decision based on that information. The output needs to be latched until the reset switch is pressed. This would have to be a simpler alarm system that what could be built using a PIC controller. However there is no support for showing which alarms were triggered or the order, as this would require considerable planning outside this simple idea.

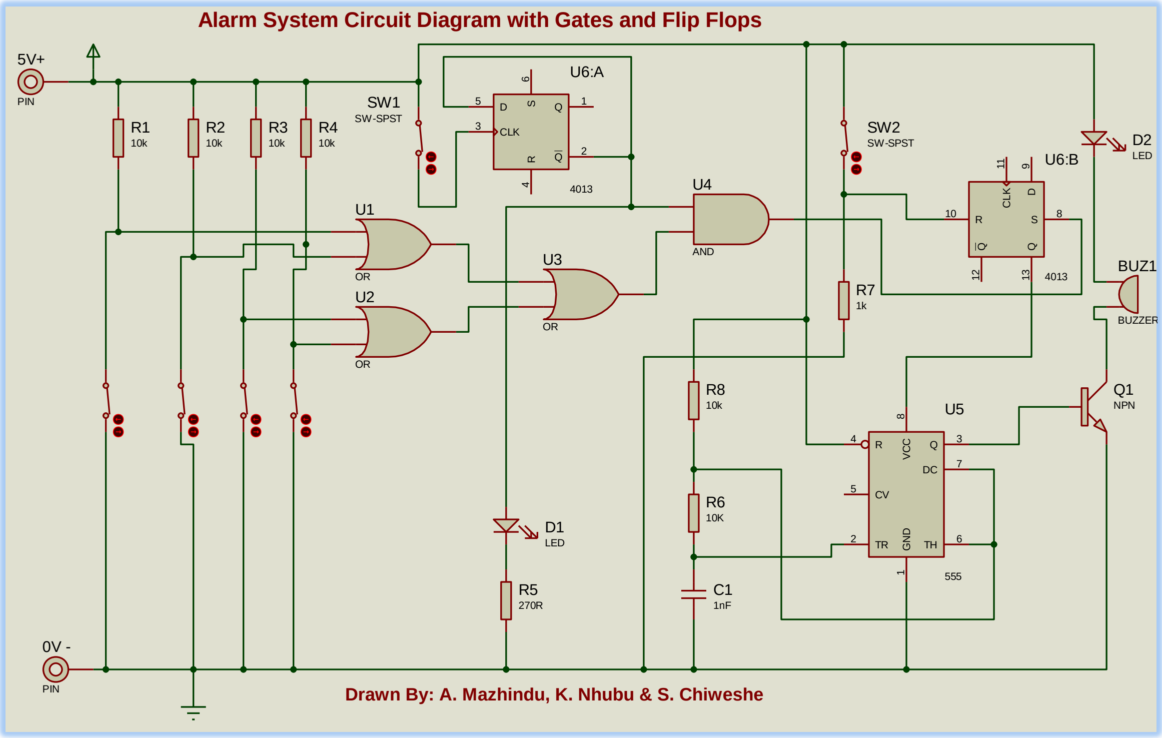


Figure 5: Alarm System Circuit Diagram with Gates and Flip Flops

Chosen Solution

A final decision has been made based on our control centre around a PIC controller, however to reduce the complexity of the program, the alarm should be implemented in external chips. This would be possible to use a Latching D-Type flip-flop for the Arm / Disarm switch.
We also need to consider that the PIC controller requires a regulated power supply of 5V and it needs to be a stable power supply. This will be investigated in the sub system designs. Also the PIC controller requires a clock pulse to operate, at the desired frequency of operation. As the device runs at 10 MHz, a decision to operate at maximum frequency was made. The device can be clocked from a simple Resistor/Capacitor combination using its internal oscillator, or the provision can be made to use a quartz crystal to resonate at the desired frequency. As the RC solution is much simpler, it is likely that this will be the solution to be implemented.

Sub-system Division

1. 12V Power Supply
2. Arm Disarm Switch
3. 12V Heavy Duty Output
4. Red Alarm and Green Armed LED's
5. 4 Zone Status LED's and 4 Zone Inputs
6. Reset Switch
7. PIC Controller

Description of 12V Power Supply

The alarm system requires two voltage levels for operation. The 12V supplied to the control panel, which is in turn distributed to the sensors and to the alarm outputs. Then the PIC controller and D-Type Flip-Flop Latch however require a 5V power supply.
To supply this voltage we use a regulation IC, such as the L7805CV chip, we have obtained the information from the data book for the IC

Diagram

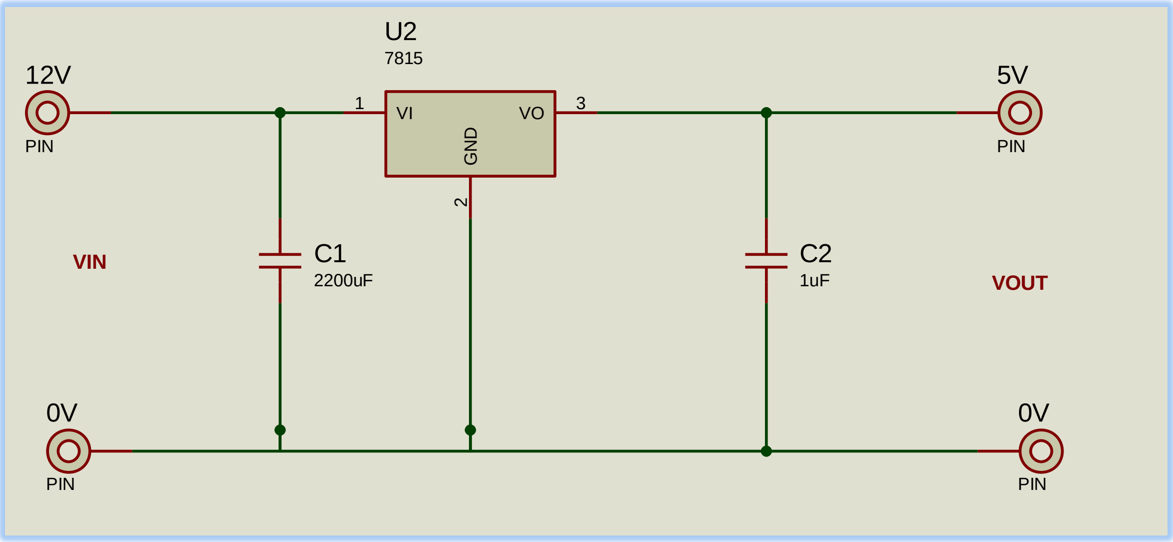


Figure 6: Wiring Diagram of an IC Chip (L7805CV)/ Regulation

- Pin 1 is connected to the 12V Positive power supply rail
- Pin 3 is connected to the 0V Negative power supply rail
- Pin 2 is used as the 5V positive rail, with the existing negative rail

A smoothing electrolytic capacitor of 2200µF in place of the 0.33µF capacitor and a tantalum lead capacitor of 1µF in place of the 0.1µF capacitor. A heat sink is attached onto the L7805CV IC to dissipate the heat generated.

Testing

After wiring up the IC properly, the voltage across the V_{out} of the IC and ground should be measured, so the IC and subsystem will be deemed to be working fine. When wiring up, safety precautions are to be followed especially for IC connections.

Arm/Disarm switch and D type latch

The PIC controller requires an input 1/ON to enter alarmed mode, so that the inputs are scanned. The pin requires a normal CMOS logic signal of 0V - 5V from the switch. The same type of switch for the reset and Arm / Disarm will be used.
The signal from this switch will be divided by two in order to give a latching input to the PIC. To achieve this with a D-Type Flip-Flop, two counters or latch will be implemented.
The D-type flip flop used is a SN74HC74N device, which contains two flip-flops.

Diagram

To make this IC divide into 2, the Q' output is fed back in as the input of the left Flip-Flop. The output from the low switch is wired to the Clock input. The output is taken from the Q output.

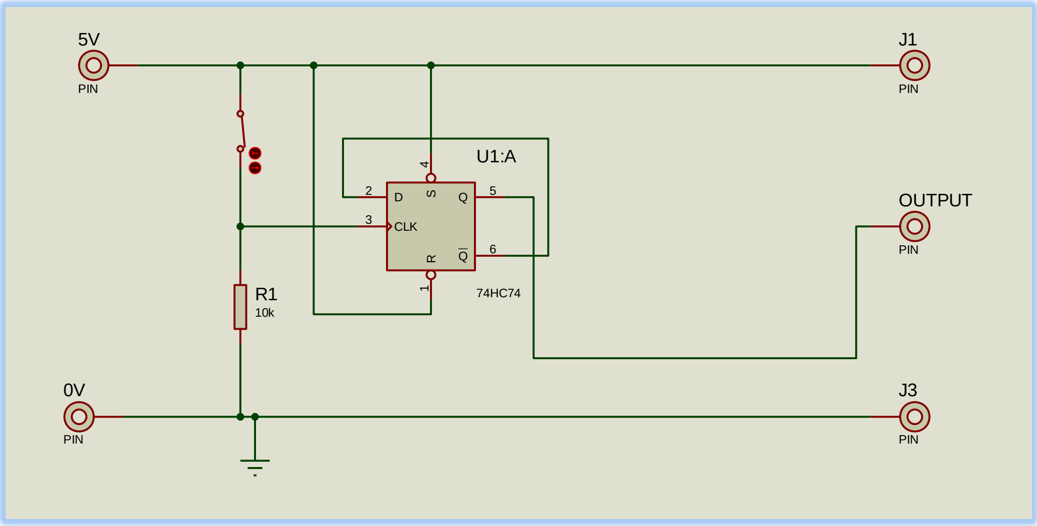


Figure 7: D- Type Flip Flop

Solution

The sub-system of arm/disarm switch D-type flip flop incorporated a SN74HC14 IC (CMOS Hex Schmitt-Trigger Inverter and it is arranged as follows to produce a clean de-bounce output. Using a D-type flip flop will only output toggle or the output could remain on initial state.

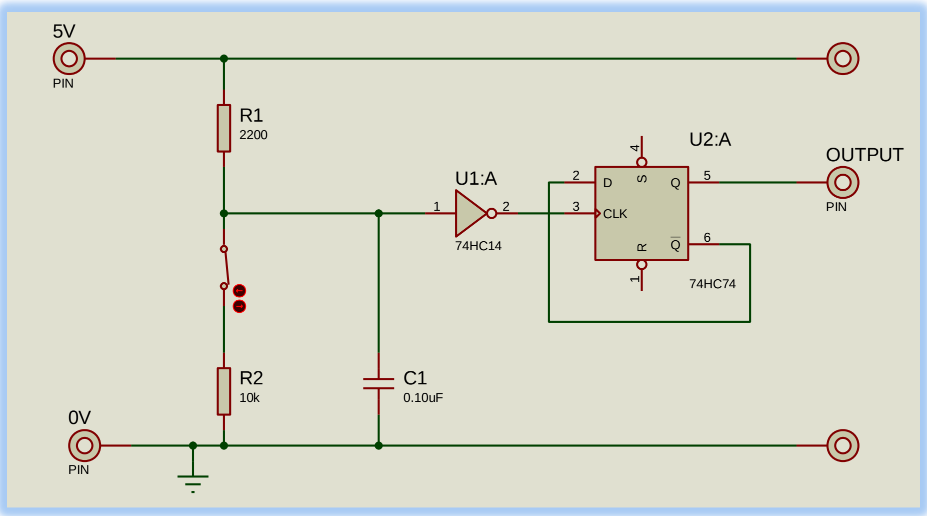


Figure 8: Inverter

D-TYPE FLIP FLOP AND INVERTER

The input from the switch is de-bounced by the Schmitt inverter, and the clean input is then passed into the lock input of the Flip-Flop. Each complete cycle of the switch alternates the output from the flip-flop, which is the output of this subsystem. The output is a digital CMOS 5V / 0V output Only half of the flip-flop and one of the six inverters in the hex inverters are used.
The output from this sub system is fed into the PIC Controller on PortA (Bit 0).

Testing

Once wiring is completed the latching action of the D-type will be tested using a multi-meter and the output alternated from a few millivolts (0V) to 5.01V (5V) as expected.

Heavy Duty Output

As the power output for the alarm siren and strobe light has to drive at least 500mA of current, a system that can handle loads was used. The subsystem needs to be either a definite on or off output, and must be driven by the logical 0V / 5V 25mA output from the PIC Controller. In order to supply the needed current a relay switch will be used. The component will switch a load up to the full potential of the power supply. The relay requires more current to activate than the PIC Controller can supply, although driving the relay with a transistor switch can solve the problem.

Diagram

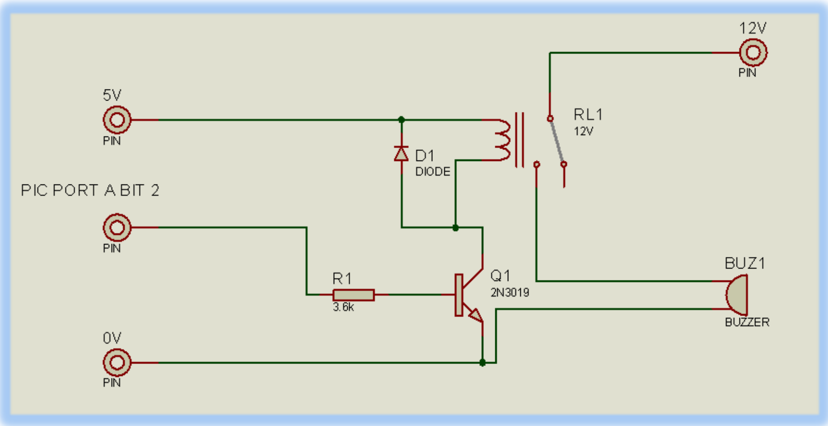


Figure 9: Heavy Duty Output with Load

Protective Resistor Calculation

In order to ensure that the transistor is not destroyed, a protective resistor has to be used. The value of this depends on the current required to flow from the base to the emitter. This base emitter current controls the current allowed to flow through the relay and then from the collector to the emitter. The ratio of currents is the gain of the transistor (hFE).
Measured the voltage from the PIC will be 5V, and the transistor has a voltage drop of 0.7V, we can work out the required potential difference of the resistor:
$VR = 5.0 - 0.7 = 4.3V$

The resistance of R can be calculated:

$$R = \frac{V}{I} = \frac{4.3}{0.0012} = \mathbf{3583 \approx 3.6k\Omega}$$

In practise a slightly smaller value of R is used to ensure that the transistor is fully saturated on, and we used **3.2kΩ**

Testing

When connected to the PIC Controller, and activated, the current flowing to the base was measured as about 2mA. This is within the current required and it activated the relay and external components as expected.

RED/GREEN ARMED LEDS

Two outputs from the PIC Controller are used to power the LEDs to give visual indication of the mode and status of the alarm system. The LED's are rated 2V/20- 25mA. The PIC controller can provide an output of 25mA from the data sheet. The PIC has a logical 1 output of 5V, a protective resistor will be used to dissipate the other 3V. Both LED's are identical in specification apart from colour, the following Protective resistor calculation applies to all.

V_{supply} 5V Current 25mA

PD over LED 2V
PD over Resistor 3V
$R = V$
$I = 3.0$
0.025 =120Ω

Diagram

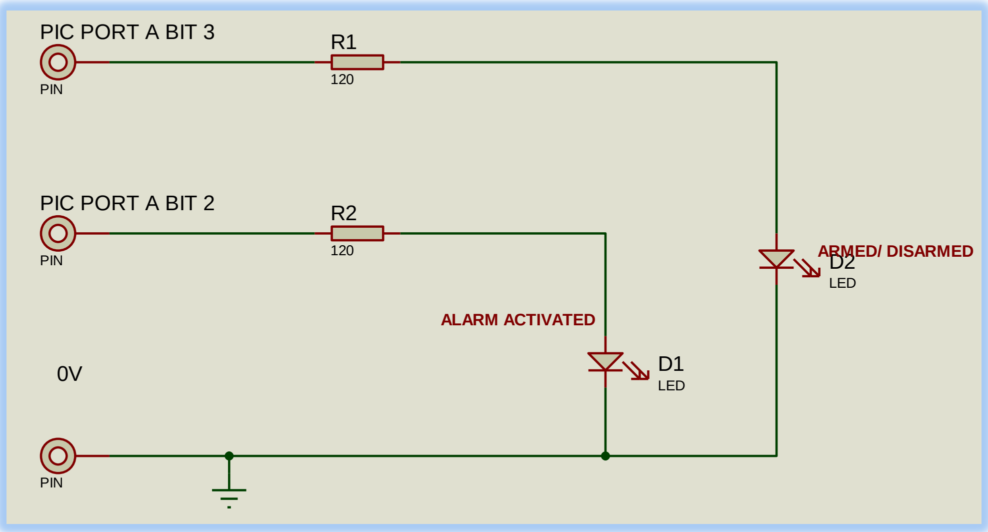


Figure 10: LED ACTIVATION

Testing

This subsystem was initially tested by connecting it to the logical outputs from the Arm/Disarm switch subsystem to check the resistors were of the right value and that the LED's were inserted with the correct polarity. The current automatically exceed 25mA when tested, so the subsystem was connected to the PIC Controller.

4 x Zone LED's and Input Loops

Four Switches simulate the sensors normally found in a burglar alarm system. They are connected as in the diagram, and when depressed raise the output to logical 1 (5V). The 4 Zone LED's are used to show if the corresponding switch has been pressed (zone triggered) and which was triggered first. These are directly driven from the pins of the PIC Controller, All four switches and LED's are connected to Port B of the PIC Controller, with the switches on the bits 0-3 (least significant) and the LED's on the upper four bits, 4-7.

Diagram

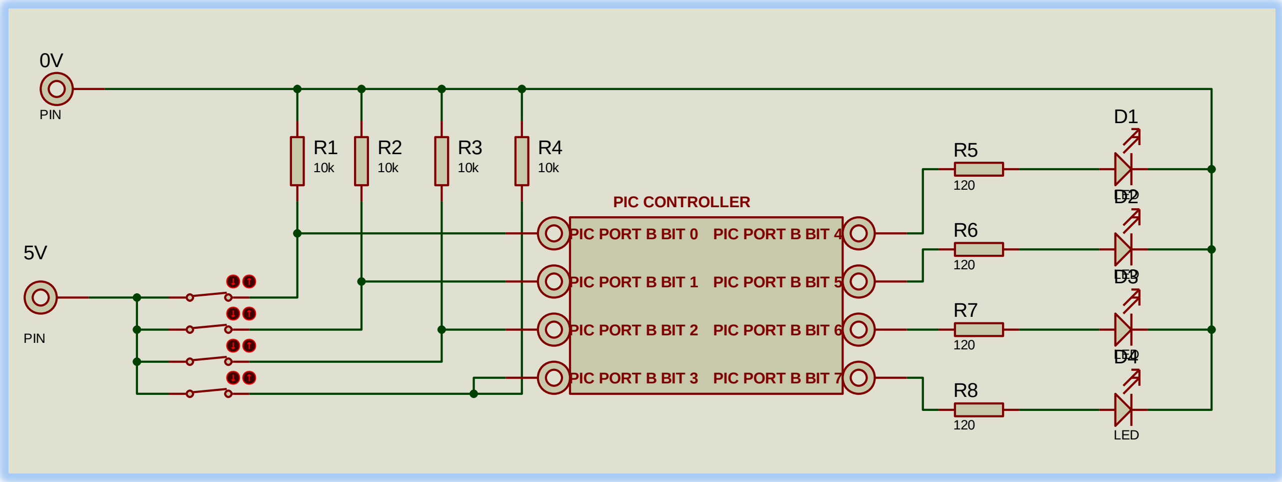


Figure 11: INPUT LED RESPONSE

Subsystems Reset Switch

The final input/output subsystem is the reset switch. This is a simple push to make switch wired up exactly the same as the zone switches above. This provides the input to the final IO Pin of the PIC Controller, and is used to reset the burglar alarm once triggered into an alarm condition.

Diagram

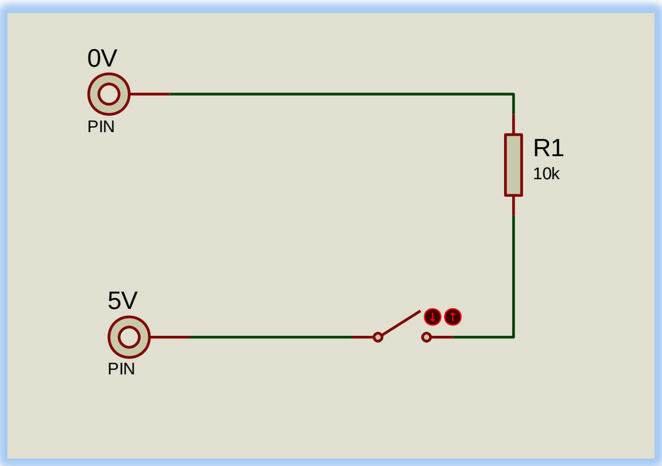
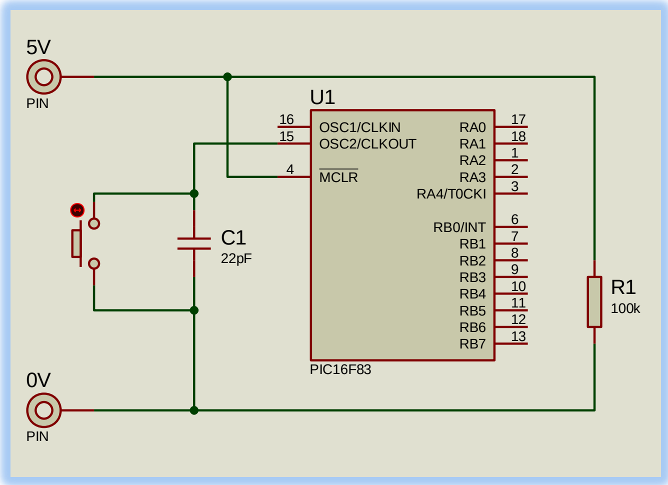


Figure 12: Switch

PIC CONTROLLER

The PIC Controller is the heart of this project and provides most of the processing of the entire system. It determines which outputs must be switched on given the current conditions of the available inputs and the situation of various internal flags which reflect the list of alarms triggered and which was first. There was an initial version which allowed us to get the project working, which was then expanded on to give the final version currently in use.

Diagram



Other connections to subsystems are omitted for simplification.

Figure 13: PIC Controller

SOFTWARE OPERATION

Procedure of a PIC16F84;

- A burglar alarm, monitoring 4 zones on PORTB 0-3.
- When an input is logical; 1 and armed signal on PORTA 0 is logical 1, then alarm sirens are issued on PORTA 2.
- PORTA 3; indicates the state of the Armed Signal (except when triggered),
- PORTA 4 indicates PIC power

COMPONENT LIST FROM FARNELL

Order Code	Qty	Description	Mftr. & Part No.	Unit Price £	Line Price £
1439530	1	MCU 8BIT 3.5K FLASH, SPDIP28	MICROCHIP - PIC16F882-I/SP	1.77	1.77
1739880	2	LOGIC, DUAL D-TYPE FLIP-FLOP, 14DIP	TEXAS INSTRUMENTS - SN74HC74N	0.16	0.32
1523916	1	IC, REGULATOR +5.0V, TUBE50	STMICROELECTRONICS - L7805CV	21	21
1780710	5	LED, 3MM, GREEN, 200MCD	BIVAR - 3UGC	0.214	1.07
7605481	5	LED, 3MM, RED, 6MCD, 700NM	LUMEX - SSL-LX3044HD	0.081	0.4
1219296	5	RESISTOR, 3K2 4 WATT 5%	WELWYN - WP4S-3K2RJA2	0.168	0.84
1735049	20	RESISTOR, 1W, 5%, 120R	VISHAY DRALORIC - AC01000001200JA100	0.24	4.8
1822683	2	CAPACITOR ALUM ELEC, 0.1ÂµF, 50V, RADIAL	NICHICON - UVZ1H0R1MDD1TD	0.106	0.21
1815302	2	CAPACITOR FILM, 0.1ÂµF, 250V, RADIAL	EPCOS - B32559C3104K.	0.1222	0.24
1832355	1	IGBT,600V,50A,TO220	INFINEON - IGP50N60T	4.27	4.27
1090691	1	Motor Starter Relay	MOELLER - NHI11PKZ2	46.2	46.2
					Subtotal: 81.12 Delivery Charges: 15.95 Total: 81.12 VAT: 16.99 **Total: 114.06**

COMPONENT LAYOUT

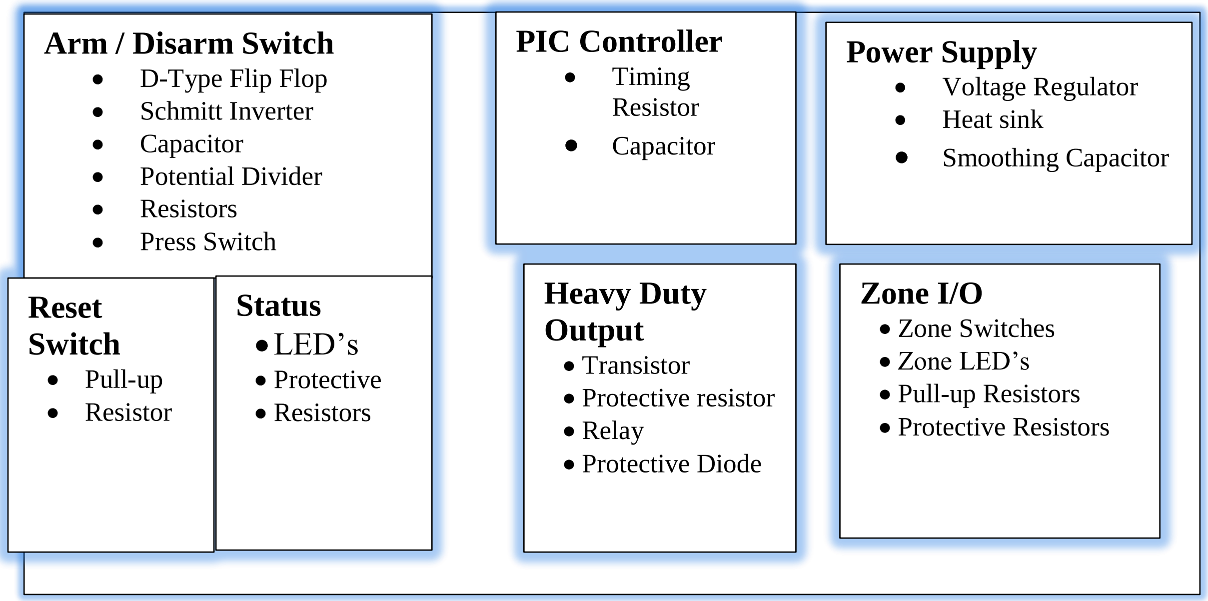


Figure 14: Component Layout

TESTING

The PIC Controller will be programmed with a test program supplied with the development kit. This is used to check that the PIC controller's processor is active. The burglar alarm program was then sent to the device and the subsystems connected together.

System Details

When the alarm system is disarmed, no LED's are activated, so there is only the IC devices activated, and so the current reading for the program does not change. If the user then presses the Arm/Disarm button, the armed LED (Green) lights to indicate the change in state. The current consumption increases to its predictable load, is that of the LED and protective resistor. As the LED's are continually changing on-off status, the current readings change a lot. When connected to the strobe and siren, the total amount of power used by the project and the external alarm components can be calculated.

$$\text{Power} = \text{Voltage} \times \text{Current}$$

$$= 12\,V \times 0.7A$$

$$= 8.4W$$

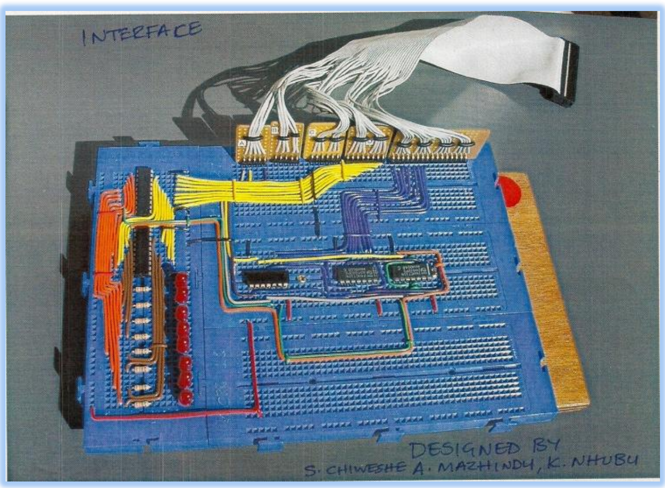
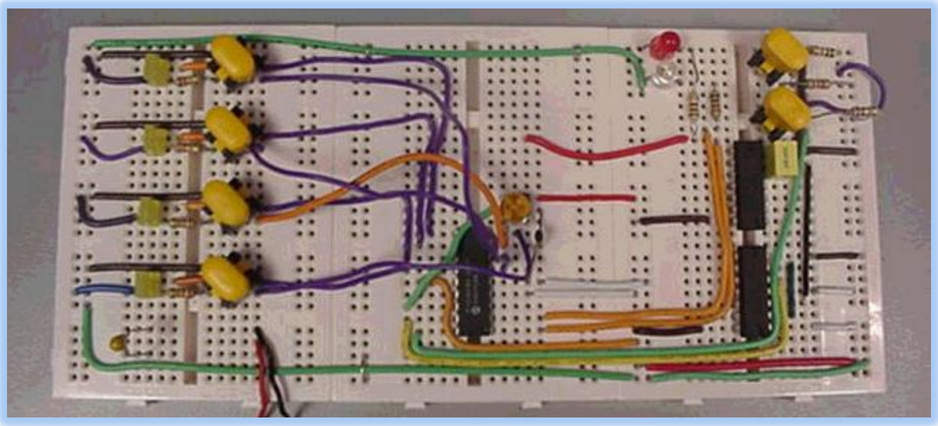


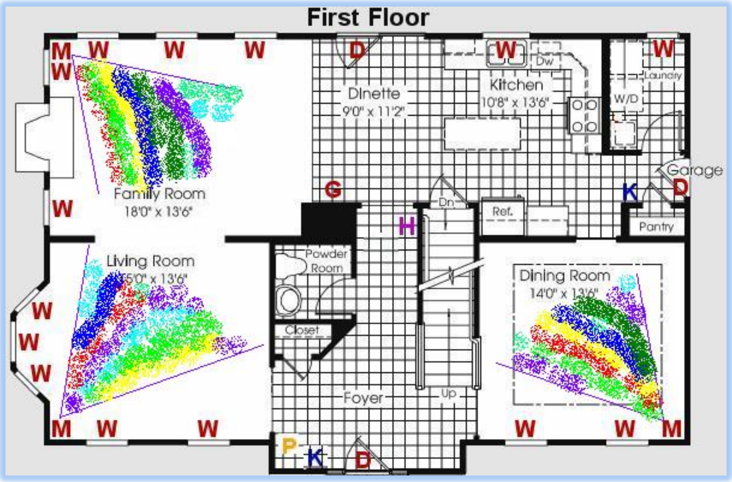
Figure 15: INTERFACE

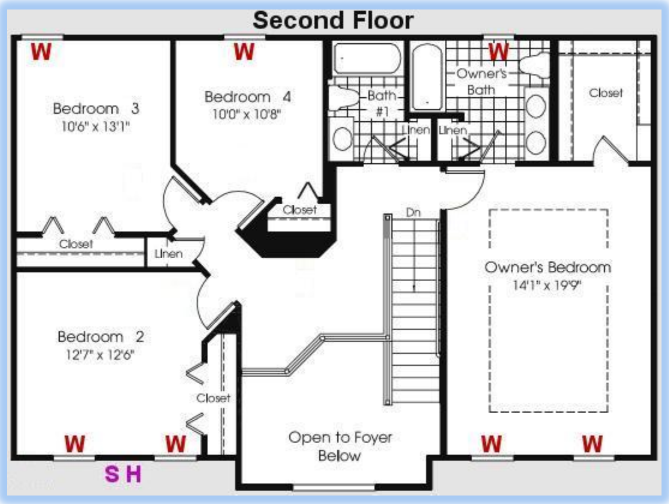


Source 3: Shucksmith, C. (2001)

Figure 16: COMPLETE ALARM SYSTEM Prototype

Figure 17: Alarm Wiring Plan





	Input Devices	Output devices
P: Main Alarm Panel **K**: Keypad	**M**: Motion Detector **D**: Door Sensor **W**: Window Sensor **G**: Glass Break Sensor	**H**: Horn/Siren **S**: Strobe Light

SAFETY

In order to ensure that health and safety procedures are followed, we ensured that the power supply voltage is constantly at a safe voltage and correct voltage for the subsystem being tested. Ensuring that power supply is switched off whilst modifying and building the project. Also careful not operate voltage regulator IC without the heat sink, as this can get hot especially when the alarm system is at full load (alarm condition) for extended periods of time.
Making sure all components are operating within their voltage and current (power) range, and those protective resistors are used when necessary.

RESULTS

- The alarm is tested on V3 board and it is able to detect intrusion from either sensor
- The program written also enables alarm activation or de-activation
- Also identifies zone of break-in
- PCB design worked as specified

FUTURE ASPECTS

- Touch activated system
- Voice recognition system
- Remote control access

CONCLUSION

An effective and reliable alarm system has been produced that works according to the specification. A system alarm is built first and then taken to a more complex and sophisticated level for enhancing security. There is room for improvement and improvisation.

- **Alarm output**: The switched alarm output is provided by the transistor and relay system, and has been tested in operation with a commercial siren and strobe flasher (see photographs on Figure 1), and can supply a load to them only limited by the maximum current of the relay (3A) and the power supply's abilities to deliver such a current.

REFERENCE

Shucksmith, C. (2001) *A Microprocessor driven four channel security system*, [Online], Available: http://www.shucksmith.co.uk/projects/burglaralarm [24 November 2010].

White, M (2010) *Pet-pet friendly- wireless burglar – alarm*, [Online], Available: http://www.all-about-the-home.co.uk [30 November 2010]

Datasheets and components: Farnell http://uk.farnell.com

LaLena, M. (2006 – 2010) *Alarm Wiring Plan*, [Online], Available: http://www.structuredhomewiring.com/AlarmPlan.aspx
[14 November 2010]

Sensors & Actuators Group_Gantt Chart_Time Plan

Project Name: Paper design Project_ Burglar Alarm

Module Name: SENSORS & ACTUATORS CY0205M

Group Members: S.Chiweshe, K Nhubu and A.Mazhindu

Today's Date: 15/11/2010 (Mon) (vertical red line)

Start Date: 15/11/2010 (Mon)

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete (Estimate)	Working Days	Days Complete	Days Remaining	Week_8	Week_9	Week_10	Week_11	Week_12
A	Paper_Design_Plan	Project_Members	15/11/10	17/11/10	2	77%	3	1	1					
1	Research & Specs	All Members	15/11/10	15/11/10	18	78%	1	14	4					
1.1	System specification	All Members	17/11/10	17/11/10	18	60%	1	10	8					
1.2	Hardware system	Alfred	22/11/10	22/11/10	30	75%	1	22	8					
1.3	Software design	Simbarashe	24/11/10	24/11/10	19	85%	1	16	3					
1.3	Alarm structure	Kwirirayi	26/11/10	26/11/10	19	85%	1	16	3					
1.3	Circuit design	Alfred	29/11/10	03/12/10	19	85%	5	16	3					
2	Methods of testing	All Members	29/11/10	29/11/10	0	50%	1	0	0					
2.1	System verfication	Alfred	29/11/10	29/11/10	17	50%	1	8	9					
3	Resources Required	All Members	23/02/10	23/02/10	286	74%	1	211	75					
3.1	Components/Prices	Simbarashe	06/12/10	06/12/10	17	60%	1	10	7					
3.2	Design tools	Kwirirayi	03/12/10	03/12/10	17	70%	1	11	6					
3.3	Implementation	Simbarashe	22/11/10	22/11/10	37	50%	1	18	19					
3.3	Programming PIC	Simbarashe	26/11/10	26/11/10	37	90%	1	33	4					
3.3	Discussion	All Members	15/11/10	15/11/10	37	90%	1	33	4					
4	Word_Processing	All Members	15/11/10	17/12/10	32	74%	25	23	9					
4.1	Finishing_Submitting	All Members	16/12/10	17/12/10	1	100%	2	1	0					

Figure 18: Time Planning

SENSORS AND ACTUATORS PAPER DESIGN

PEER ASSESSMENT

In general peer assessment involves each member of a team being given a proportion of the marks awarded agreed by the other members in the team. This mark should take into account the individual's contribution to both the technical and managerial aspects of the work carried out by the team as a whole. Imagine that each group has been given 100 marks and these have to be distributed amongst the team members in proportion to each individual's contribution measured as a % of the group mark. For example, a team comprising members A, B and C agrees that member A has combined the role of report writing with a significant amount of design work, to the extent that the team agrees their contribution is 45% of the total team effort and that of members B and C are 30% and 25% respectively. If the initial mark for the group report is 68% then member A should be given 45% of $3\times68\% = 92\%$, member B should be given 30% of $3\times68\% = 61\%$ and member C should be given 25% of $3\times68\% = 51\%$. The individual peer assessments for a group must always add up to 100% and if the individual contributions are the same then each member gets the original mark. In order to avoid contention, the team members should exercise diplomacy in the first instance but in the event of major disagreements Dr Jiang should be called in to arbitrate. Bear in mind that the ideal outcome would be an equal division of marks amongst the team members.

Note The Peer assessment calculation will be applied to only 20% of the initial mark awarded for a Paper Design and the final marks would be capped at 100%. If no peer assessment form is completed then each member of the group will be assumed to have made equal contributions to the report.

Group member's name and UB number	Signature	Peer assessment marks (Must sum to 100)
KWIRIRAYI NHUBU 09019447	**kwiri**	**30**
ALFRED MAZHINDU 09022270	**alfie**	**40**
SIMBARASHE CHIWESHE 09016352	**sim**	**30**