



An automated Roof Window System
¹Space and Atmospheric Sciences Division
²Workshop (Department)

by
T.A. Rajesh¹, S. Ramachandran¹ & G.P. Ubale²



भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
Physical Research Laboratory, Ahmedabad



An automated Roof Window System
¹Space and Atmospheric Sciences Division
²Workshop (Department)

by
T.A. Rajesh¹, S. Ramachandran¹ & G.P. Ubale²



भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
Physical Research Laboratory, Ahmedabad

***Disclaimer:** This technical report is based on the work carried out by the authors at PRL. It is assumed that due credit/references are provided by the authors. PRL assures no liability whatsoever for any acts of omissions and any of the issues arising due to the use of results.*

*Published by
The Dean's office, PRL.*

Contents

1	Introduction	1
2	AC Induction Motor	1
3	Hardware Design and Implementation	2
4	Software Design and Implementation	7
5	Mechanical System	8
6	Application case study	9
7	Summary	11
8	Acknowledgements	11
9	References	11
10	Appendix A: Flowchart	12
11	Appendix B: GUI Screen shots	13
12	Appendix C: Roof window Images	15

An automated Roof Window System

T.A. Rajesh*, S. Ramachandran & G.P. Ubale

Physical Research Laboratory, Ahmedabad

(*rajeshta@prl.res.in)

Abstract: In this technical note, we discuss about the design, development and implementation of an automated roof window system. A single phase induction motor is used to operate the roof window and its operations can be controlled manually as well as through a computer. The complete mechanical system, motor driver unit, control electronics and the associated software for the data acquisition over USB using LabJack U12 data acquisition module are developed in-house to drive a single phase induction motor. As a case study, we discuss about the automated roof window system application for the light detection and ranging (LIDAR) instrument. The details of the complete mechanical system, electrical & electronic hardware systems and the driver & control software are presented in this note.

1. Introduction

A roof window is a transparent or translucent opening in a roof structure that allows the passage of light/air/sound. We will discuss here a top hung transparent opening on the roof structure. It is basically a motorized roof opening, which can be opened or closed through an electrical power driven motor. Such roof window has various applications in industry, house hold, atmospheric research laboratory etc. In the area of atmospheric research it can be used with the following instrument; light detection and ranging (LIDAR), sky imagers, day/night glow photometers, etc.

The objective of our work is to design and implement a roof window system with the following features (1) high strength (2) dust proof & water resistance (during close condition) (3) manual as well as computer operation (4) Electrical isolation (5) limit switches status decoding (6) tracking the window movement operation (7) GUI application software control & interface. The present work discusses the design, development and implementation of the automated top hung roof window system. It also discusses the versatile in house developed control electronics and an application software package for the data acquisition and control through Labjack U12 device. The detailed descriptions of the various hardware (AC induction motor, motor drive mechanism, induction motor control unit, AC power line detector unit, ultrasound distance sensor unit and rain detector), software and mechanical sub systems are discussed further.

2. AC Induction Motor

AC Induction motors are the most common motors used in home appliances, as well as in industrial motion control systems [1]. The main advantages of AC induction motors are their simple and rugged design, low cost and low maintenance. We have used the single-phase AC induction motor in the present work and will discuss the same further. It consists of stator and rotor. The stator is the stationary electrical part of the motor and rotor is the rotating part of the motor. The stator of a single-phase AC induction motor has

two windings, the main winding (low resistance and high inductive reactance) and the start winding (high resistance and low reactance). The stator and rotor are separated by an air gap which allows free rotation of the rotor.

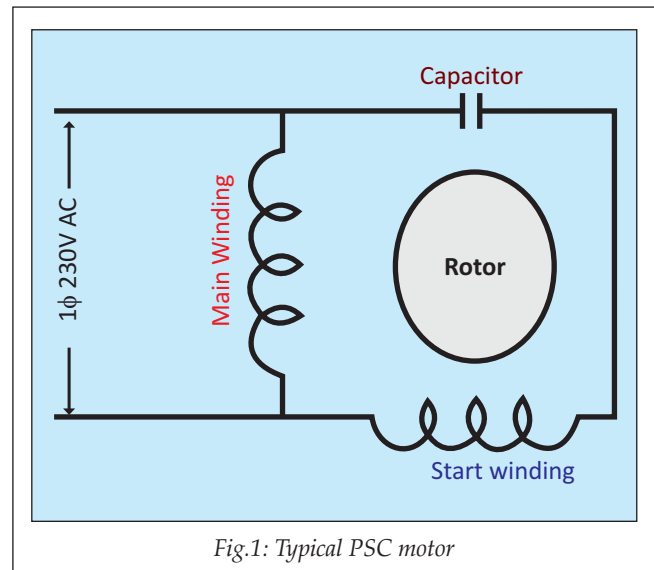
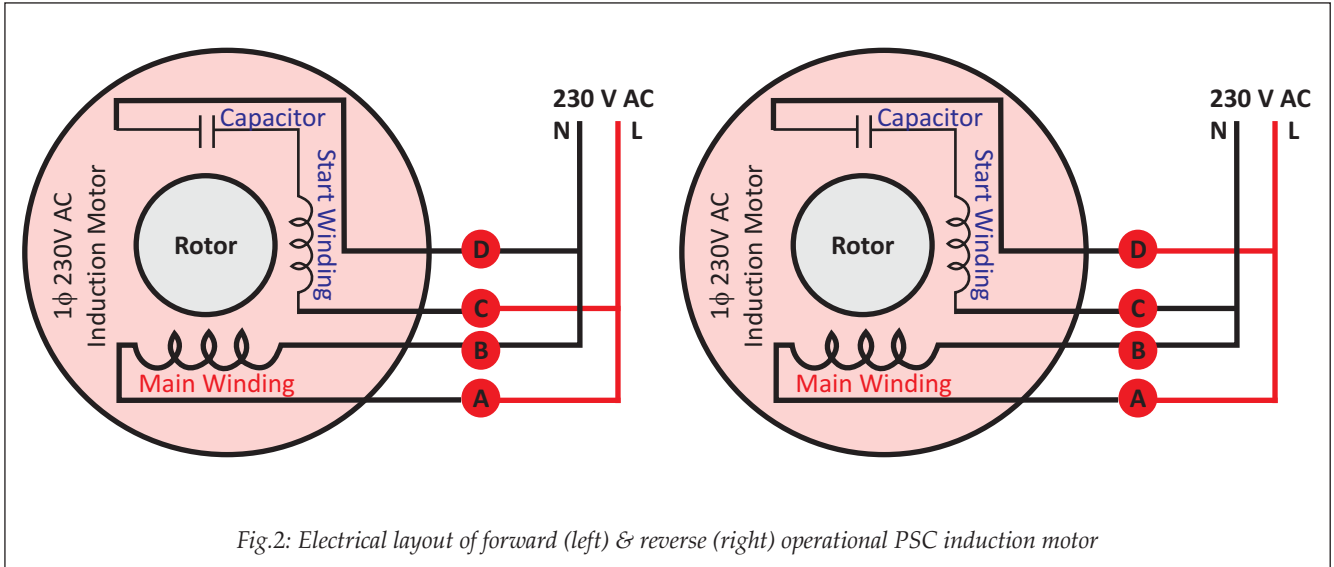


Fig.1: Typical PSC motor

The single-phase AC induction motors has various starting mechanisms but in the present work we will discuss only permanent split capacitor (PSC) induction motor as illustrated in figure 1. The start winding has a series capacitor, when the AC supply voltage is applied; current in the main winding & start winding lag behind the supply voltage and the current through the start winding leads the main winding current because of their different reactance. The windings develop fields that are out of phase, which creates a rotating magnetic field in the stator. This applies torque to the rotor resulting in starting the motor. We have used the single-phase 230 V AC Induction motor from Hareehar Machine Tools, of rating 0.5 horse power (HP) & 1440 rotation per minute (RPM).

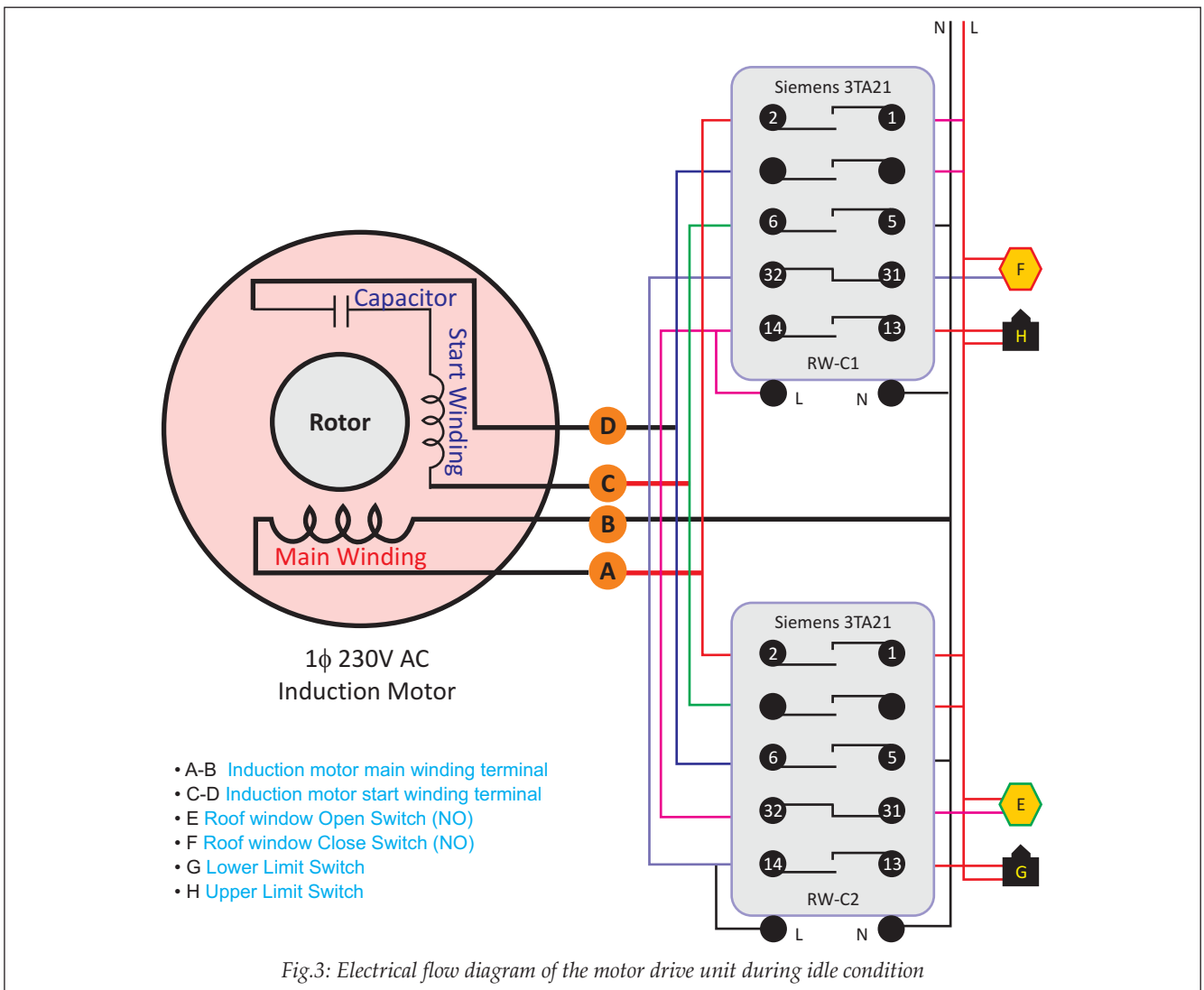
The rotation of the above discussed motor can be reversed by reversing the AC power supply connection to either the main winding or the start windings, creating a magnetic field rotating in the opposite direction. Figure 2 illustrates the induction motor forward and reverse operational electrical schematic, where the power supply connection to start winding is reversed, which is used in the present work. The motor main winding terminals A & B are connected to 230 V AC line & neutral supply respectively. The start winding is in series with a capacitor, terminals C & D are connected to 230 V AC line & neutral supply respectively for the forward rotation of the motor. In order to reverse the direction of motor the terminals C & D are connected to neutral & line supply respectively.



3. Hardware Design and Implementation

The hardware control system consists of electrical and electronic subsystems for manual and computer controlled operations of the induction motor. The induction motor manual control unit consists of contactors (it is an electrically

controlled switch having multiple contacts and the contacts are combinations of normally open and normally close configuration) [2], limit switches and push button switches. Figure 3 shows the electrical flow diagram of the motor drive unit during its idle condition. We have used Siemens 3TA21



contactors, which has coil voltage of 230 V AC, four normally-open and one normally-close contacts. Two industrial grade limit switches: lower and upper limit switches are used to limit the open and close position of the roof window (the roof window driven by the motor are discussed in details at the mechanical system section). When the window in close (home) position, the lower and upper limit switches state are

in normally opened (NO) and normally connected (NC) mode respectively and vice versa during its opened condition. The contactors, limit switches and push button switches are electrically wired such that the motor can be operated manually in forward and reverse direction, resulting in opening and closing of the roof window. Table 1 illustrates the status of the motor, push button switches, contactors and limit

Motor in idle state (Roof window in closed position)	
Component	Status
Push button Switches	Open switch – OPEN Close switch - OPEN
Contactor RW-C1	Idle
Contactor RW-C2	Idle
Limit Switches	Lower limit switch – OPEN Upper limit switch – CLOSE
Induction Motor	Idle

Table 1: Status of components when window is closed

Motor rotation in forward direction (window opening)	
Component	Status
Push button Switches	Open switch – Trigger Close switch - OPEN
Contactor RW-C1	Active <ul style="list-style-type: none"> • Contacts 1-2, 3-4, 5-6 and 13-14 are Connected • Contact 31-32 is open
Contactor RW-C2	Idle
Limit Switches	Lower limit switch – CLOSE Upper limit switch – CLOSE
Induction Motor	Active - Roof window in opening mode <ul style="list-style-type: none"> • Motor terminal A is connected to RW-C1 #2 • Motor terminal C & D are connected to RW-C1 #6 & #4

Table 2: Status of components when window is opening

Motor in idle state (window in opened position)	
Component	Status
Push button Switches	Open switch – OPEN Close switch - OPEN
Contactors RW-C1	Idle
Contactors RW-C2	Idle
Limit Switches	Lower limit switch – CLOSE Upper limit switch – OPEN
Induction Motor	Idle

Table 3: Status of components when window is opened

Motor rotation in Reverse direction (window closing)	
Component	Status
Push button Switches	Open switch – OPEN Close switch - Trigger
Contactors RW-C1	Idle
Contactors RW-C2	Active <ul style="list-style-type: none"> • Contacts 1-2, 3-4, 5-6 and 13-14 are Connected • Contact 31-32 is open
Limit Switches	Lower limit switch – CLOSE Upper limit switch – CLOSE
Induction Motor	Active - Roof window in closing mode <ul style="list-style-type: none"> • Motor terminal A is connected to RW-C2 #2 • Motor terminal C & D are connected to RW-C2 #4 & #6

Table 4: Status of components when window is closing

switches in the idle state of motor (window is closed). The push button switches allows electricity to flow between its contacts only when it is active/triggered.

When the open push button switch is triggered, it activates the contactor RW-C1 through the contacts 31-32 of contactor RW-C2. The contactor RW-C1 remains in the active

(energized) state through the power supply from the upper limit switch (RW-C1-13&14), even though the open push button switch circuit is broken. The motor now rotates in forward direction resulting in the opening of roof window. The roof window during the opening condition pushes the upper limit switch and it deactivates the contactor RW-C1. The various states of the system components are shown in table 2.

Table 3 illustrates the status of the various components when the window is in opened position. As long as the roof window is in opened condition the upper limit switch is in normally opened (NO) state. When the close push button switch is triggered, the contactor RW-C2 is activated through the contacts 31-32 of contactor RW-C1. The contactor RW-C2 is active even after the close push button switch is released through the power supply from the lower limit switch (RW-C2-13&14). Accordingly, the motor rotates in the reverse direction resulting in the closing of the roof window. When the roof window pushes the lower limit switch, it deactivates the RW-C2. The states of the various components are shown in table 4 for the roof window in closing mode.

Figure 4 illustrates the schematic of the computer controlled operations of an induction motor. The basic control electronics building block consists of an induction motor control unit, USB data acquisition system, ultrasound distance sensor unit and a rain detector unit. The induction motor control unit generates the open and close pulses for the above discussed induction motor driver unit, in order to operate the motor for opening and closing the roof window respectively.

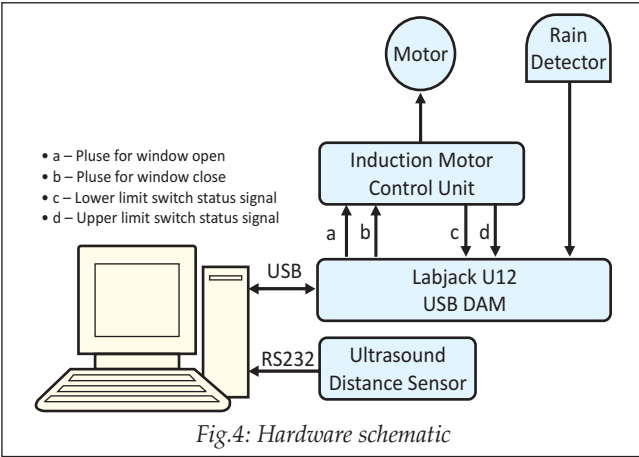


Fig.4: Hardware schematic

The software (discussed in details at the software design and implementation section) in the computer reads the window position (close or open) and it issues the window open and close signal through the U12 data acquisition and control device. The U12 is a USB-based multifunction data acquisition and control device from LabJack Corporation [3]. The U12 device is connected to computer through USB interface and the following signals are interfaced through its digital I/O (DIO) port; (1) pulse to open roof window (2) pulse to close roof window (3) status of lower limit switch (4) status of upper limit switch & (5) rain detector output as illustrated in figure 4. The status of the roof window limit switches are converted into digital (0 & 5V) logic state using the electronic circuit as illustrated in figure 5. We have used power line detector IC MID400 from Fairchild Semiconductor which is an optically isolated AC line-to-logic interface device. It consists of two back to back GaAs light emitting diodes (LED) and photo diode detector amplifier [4]. The AC line voltage is monitored by the GaAs LED in series with an external resistor of 100KΩ. The GaAs LED will convert the alternating current into light energy. A high gain integrated photo diode detector amplifier senses the LED current and drives the output. As shown in figure 5, the IC#1 & IC#2 is used to sense the status of upper limit switch (RW-C1-13) and lower limit switch (RW-C2-13) respectively. Its output digital logic state (0 or 5V DC) D2&D3 are used to infer the position of the roof window.

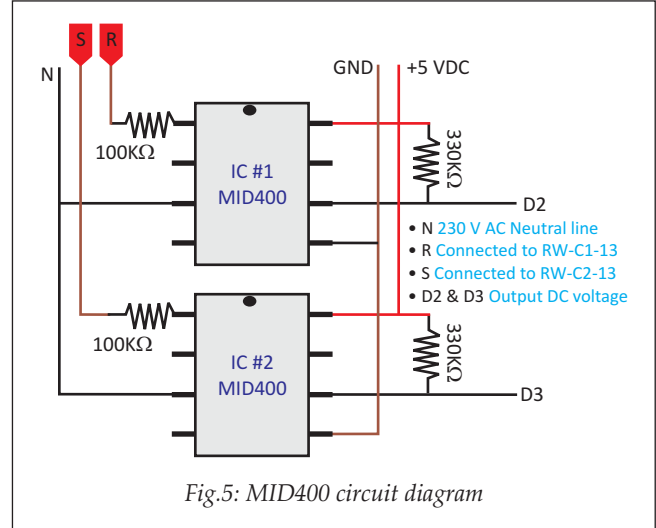


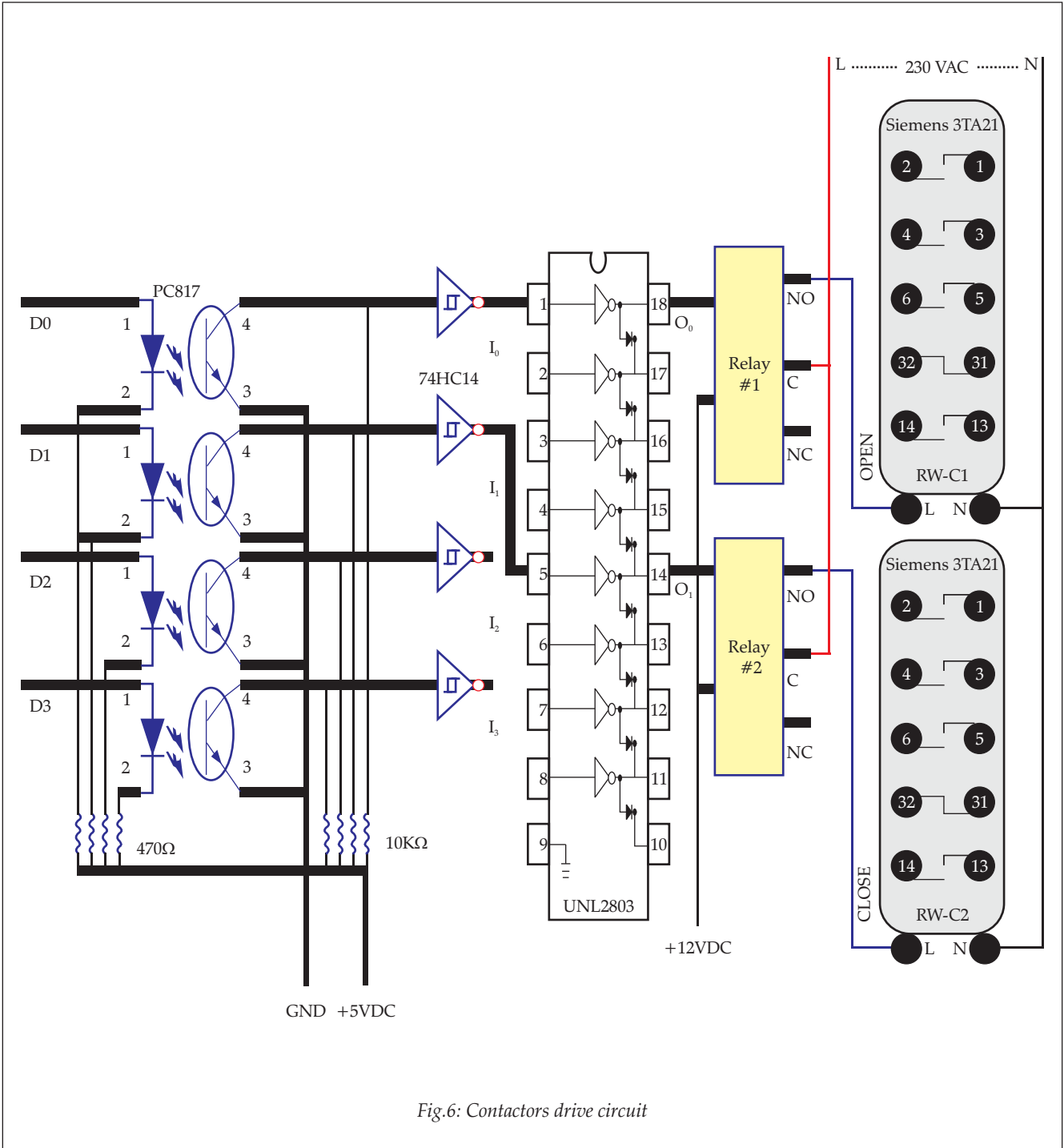
Fig.5: MID400 circuit diagram

The controls (open & close) and the status (limit switches) signals to/from the induction motor control unit are optically isolated from the computer. We have used photocoupler PC817 from Sharp which features high isolation voltage between input and output ($5000 V_{rms}$) [5]. This isolation is mandatory in order to ensure the system safety during normal operation and in the standby conditions. The photocoupler output pulse is processed using a schmitt triggered 74HC14 in order to get the stabilized and noise free pulse as shown in figure 6. The D0 & D1 data bits corresponds to the window open & close signal command from the computer through the DIO port of U12 device. As discussed above the D2 & D3 signals represents the limit switches status (I_2 & I_3) and are interfaced to U12 device through its DIO ports.

The optically coupled, window control signals (I_0 & I_1) drives the electromagnetic relay (an electrically operated switch which use an electromagnet to control the switching mechanism) though a darlington driver IC ULN2803 from Motorola [6]. It allows interfacing transistor-transistor logic (TTL) signals from the computer with higher voltage/current loads. In the present work we have used 12 V DC relay with contact capacity of 10 A at 230 V AC and are operated in normally open (NO) mode. The Q_0 & Q_1 ULN2803 driver outputs activate the relay#1 and relay#2 respectively, which in turn issues the window open and close command to induction motor through the contactor RW-C1 & RW-C2 as illustrated in figure 6.

In order to protect an instrument from rain which is operating under the roof window, we have used a rain detector to sense it and close the window when it is in open condition. We have used rain detector, model RG-11 from Hydreon Corporation [7]. Figure 4 illustrates the interface schematic of the rain sensor. The signal is connected to the DIO port of the U12 device.

In addition, to observe and confirm the operations of roof window, we have developed an in house subsystem for confirming its opening and closing operations. The limit switch status will tell us the state of the window, but in order to detect the window state during its continuous movement (opening & closing) the developed system plays a very important role in updating the computer based software. In



this technique, we have converted its angular rotation into linear movement as illustrated in figure 7. The heart of the technique is an ultrasound distance sensor. It reads the distance by measuring the amount of time taken for a pulse of sound (40 kHz) to travel to a particular surface and return as the reflected echo. We have used the ultrasound distance sensor model #1166 from Sunrom Technologies in the present study [8]. The sensor has minimum range of 10 cm, maximum range of 400 cm, accuracy of ± 1 cm and resolution of 0.1 cm. As shown in figure 7 the ultrasound distance sensor is mounted at the base of a 3.5 inch diameter PVC tube. An aluminum plate of diameter 3 inch and thickness 4mm is hung inside the tube through a nylon rope. The rope is tied to the window frame

through a pulley assembly. The angular rotation of the window is now converted into the linear movement of the aluminum plate inside the tube. The ultrasound distance sensor measure the distance of the aluminum plate from its reference positions (P1 & P2). The plate inside the PVC tube is in position P1 & P2 when the roof window is at closed & opened condition respectively (figures 7). The plate position varies between P1 & P2 during the opening or closing of the window and the ultrasound distance sensor measures this variation, which indicates the proper operation of the window (opening or closing). The serial TTL level output data from the module #1166 is connected to computer RS232 port through Max232 TTL to RS232 level shifter circuit.

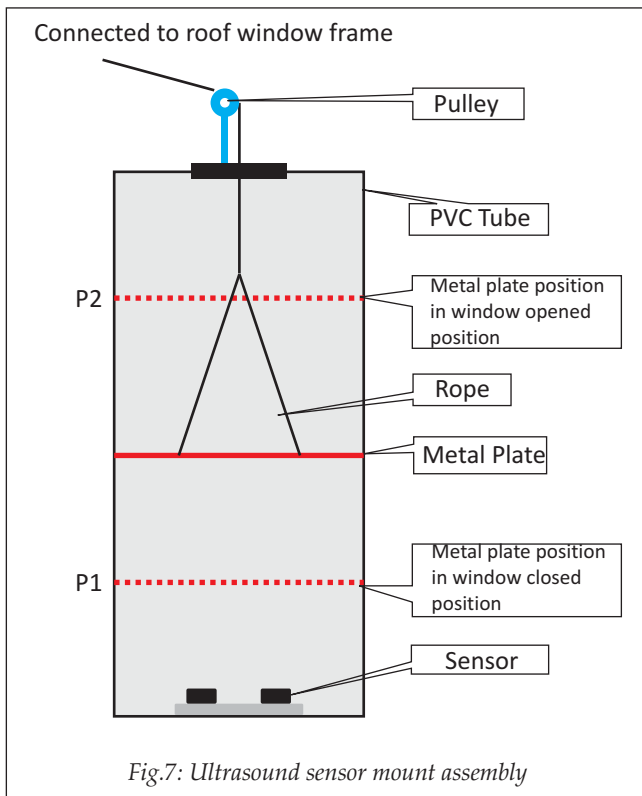


Fig.7: Ultrasound sensor mount assembly

The roof window travels a linear distance of approximately 200 cm from the close (home) to open position, measured at its edges. If the two extreme window edge positions be represented as x_1 (close position) and x_2 (open position) then the corresponding ultrasound distance be represented by y_1 and y_2 respectively. Assuming linear fitting, the slope (m) and intercept (c) can be given as

$$m = \frac{(Y_2 - Y_1)}{(X_2 - X_1)}$$

$$c = Y_1 - (mX_1)$$

At any instance of time, for the measured ultrasound distance (x), the window position (y) is calculated as

$$Y = mx + c.$$

As discussed, this distance data is used to monitor and confirm the operation of the window.

4. Software Design and Implementation

The data acquisition and control program is written in Visual Basic 6.0 (VB). It is an event-driven programming language and integrated development environment from Microsoft [9]. It enables the rapid application development of graphical user interface (GUI) applications.

The GUI application software running in the computer is interfaced to U12 device and ultrasound sensor module through USB and RS232 port respectively. The software communicates with the ports through ActiveX control (it is a set of rules defined to share information using Microsoft ActiveX technologies). We have used ActiveX control "ljackuw" from LabJack Corporation in order to communicate with U12 device and "mscomm32" came with VB 6.0 to read the data from the ultrasound distance sensor module. The flowchart for the present work is shown in appendix A.

It reads the limit switches status and controls the motor rotation through U12 device. The versatile software is made to control two identical windows A and B. The system generates the distinguishable addresses for the close, open, power OFF and opening/closing positions. The rain detector unit generates a software interrupt signal to close the window, if it is in open condition. The software acquires the data every second in order to confirm the status of the window. The GUI software logs, each and every user, and system activity for any future troubleshooting.

The "Roof Window Application Software" is the roof window system data acquisition and control application software. It has the following menu: Config, Control, Refresh, About and Exit as shown in appendix B. The details are discussed below

4.1. Config Menu

The following parameters need to be configured in the Setup frame

- Station: The location name is entered as station name.
- Active Window: As discussed earlier, the hardware and software are designed and implemented for two identical windows (A and B) system. The user can select the active window.
- Window ID: The unique and distinct window ID are entered for A and B systems, for a smooth software operation.
- Displacement Sensor: The user can select the displacement sensor for the active window.
- Remarks: The user can enter the remarks for each window.
- Rain Sensor: The check box is enabled to keep the rain sensor as an integrated part of the system. By default it is enabled and when it detects the rain drops, it generates a software interrupt to issue close (home) command to window control electronics.
- Displacement Sensor setting: The displacement sensor is connected to the computer RS232 port. The user can enter the com port to which the sensor is connected. Also each sensor calibration data are entered.
- Port settings: The default computer RS232 port settings are set as 9600, N, 8, 1.
- Log events: This check box is enabled to log the various user and system related activities. By default it is enabled.
- Logfile path: The directory path "c:\TWUS" is the location for the log and system files.
- Data acquisition rate: The user can choose the data acquisition rate of the software in order to control and access data from U12 device and displacement sensor module.
- Display Displacement Sensor Raw data: In order to read the raw displacement sensor data this check box is enabled, it is used to get the data in order to feed the displacement sensor settings parameters.
- Save + Back: The setup parameters are saved in the file setup.txt into the directory "c:\TWUS".

4.2. Control menu

The control menu shows the configured station, current date and time. It has two frames for each window. Each frame displays the window ID, status, displacement, time of

activation and remarks for the respective window. The user can open or close the window by selecting the respective command button. When the open command button is clicked, the status shows the current window position, the displacement shows the linear distance travelled by window in cm and the activated label displays the time (seconds) taken in opening the window. Similar messages are displayed for the close operation.

4.3. Refresh menu

It is used to reinitialize and reload the program variables and programs respectively.

4.4. Exit

The software can be terminated through the exit menu. Before quitting, it closes all files and ports.

5. Mechanical System

Figure 9 shows the schematic of the roof window system. The mechanical system consists of three sections (1) base structure (2) window support & frame structure and (3) drives assembly. The base structure consists of mild steel (MS) I beam frame of thickness 10 cm and dimension 130 x 130 cm welded together with mounting brackets so as to fix it to the roof. The windows support & frame structure is fabricated from MS angle (1 inch) frame of size 140 x 140 cm with MS plate grids in order to strengthen the structure as illustrated in figure 9. A poly carbonate fiber sheet (water resistant) of thickness 3 mm and dimension 150 x 150 cm is glued on the window structure. The drives assembly section consist of a motor, reduction gear box, 1.5 inch MS axle shaft, Stainless Steel (SS) rope of diameter 4 mm and pulley set with guide, MS base for motor mounting and limit switch mounting assembly as illustrated in appendix C.

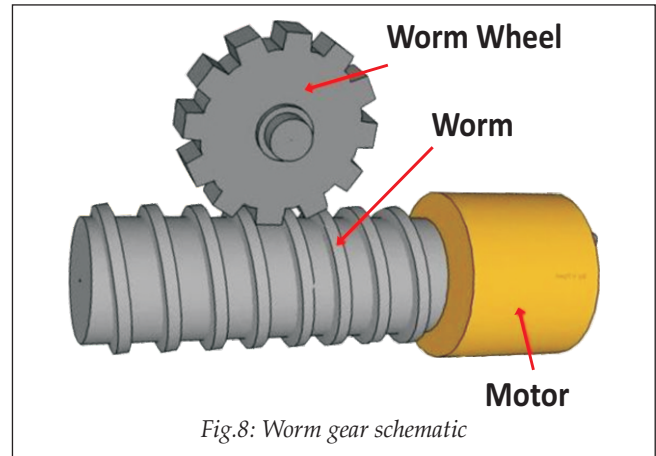


Fig.8: Worm gear schematic

The heart of the drives assembly unit is the worm gear box. It consists of a screw-like worm that meshes with a larger gear, usually called a worm wheel as shown in figure 8 [10]. The worm acts as a screw, several revolutions of which pull the wheel through a single revolution. Worm-gear shafts are perpendicular, non-intersecting, and can be positioned in a variety of orientations. It has an interesting property that: the worm can easily turn the wheel, but the worm wheel cannot turn the worm. This is because the angle on the worm is so shallow that when the wheel tries to spin it, the friction between the wheel and the worm holds the worm in place. This feature is useful as the locking feature or as a brake, when the motor is not turning. In the present work, we have used the worm gear box with reduction ratio of 60:1 and load bearing capacity of 150 kg. The axle of the worm wheel is mechanically extended as a shaft (diameter 1.5 inch MS) for the system. The shaft consists of two pulleys (P1 & P2) and the window frame is welded onto it as illustrated in figure 9.

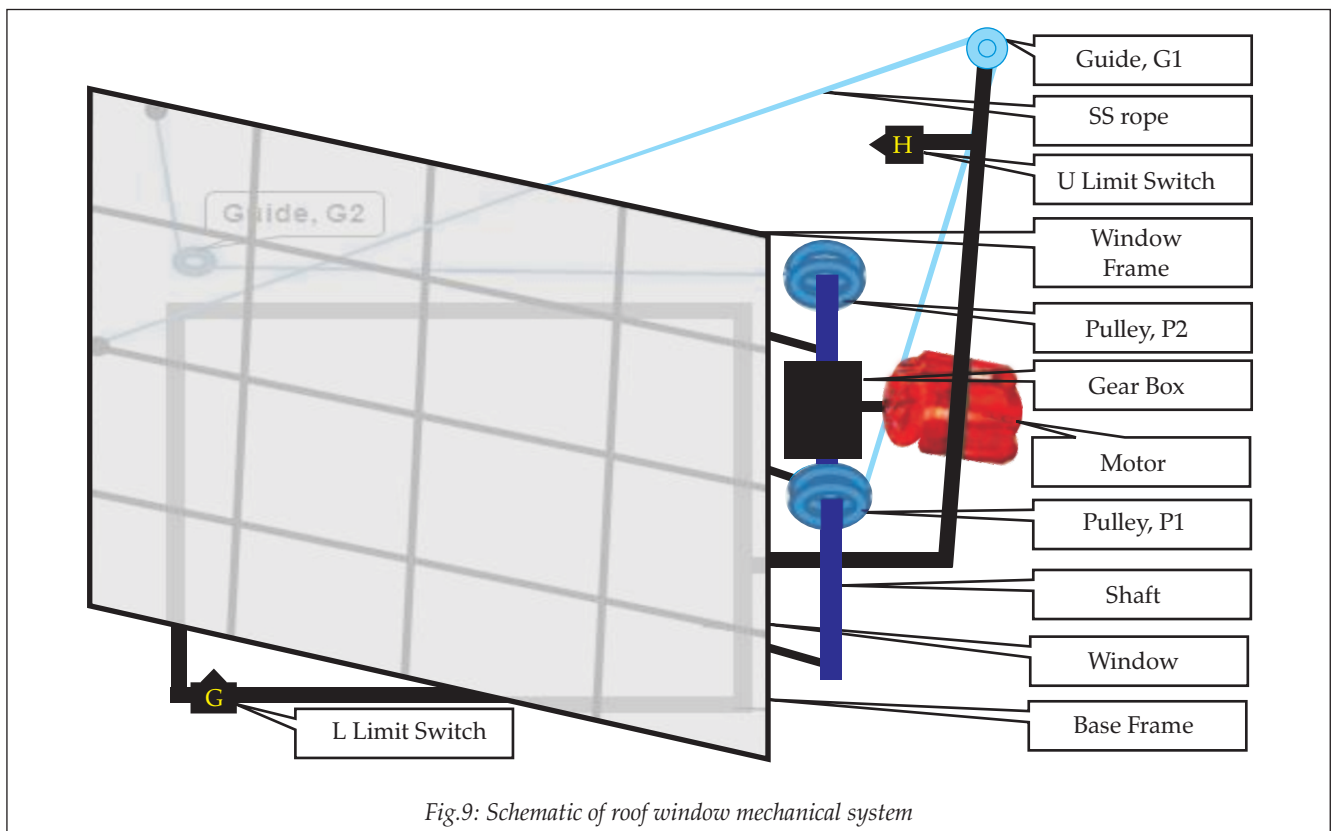


Fig.9: Schematic of roof window mechanical system

The weight of window support & frame section is approximately 50 kg and its movement is controlled through rope and pulley drive mechanism. In this mechanism the SS rope of diameter 4 mm is transmitting a linear motive force to a load through the pulley for the purpose of pulling the load [11]. The rope is attached at one end to a fixed point and to the center of the movable pulley on the other end through a guide.

The motor torque is transmitted to the load (window) through the gear box. The window support structure is designed to open it to 100 degree with respect to its home (close) position. The pulley, P1 for opening the window is mounted at the center of geared axle shaft. The identical rope and pulley, P2 system is mounted at the end of the axle shaft for closing the window. When the window is opening P1 is pulling it through the guide G1 at the same time P2 is releasing the rope through its guide G2. When the window is closing, P2 now pulls the window through its guide G2 and P1 releases

the rope through its guide G1. The pulleys P1 & P2 are used to open and close the window through the guides G1 & G2 respectively. The tensions in both the ropes are adjusted for the smooth operation. The roof window takes approximately 23 seconds to open or close after the issue of command.

6. Application case study

An automated roof window system has been installed at the roof of the Aerosol Mass Spectrometer & Lidar (AMSL) lab PRL for the Light Detection And Ranging instrument (LIDAR) and is working successfully. A LIDAR is a compact and eye-safe optical instrument capable of determining the range of aerosols and clouds by firing a short pulse of laser light (at 532 nm) and measuring the time-of-flight from pulse transmission to reception of a returned signal [12]. It is vertically oriented and measures the vertical profile of aerosols. As an application of the roof window system, we will discuss here the implementation and real time working of the system.

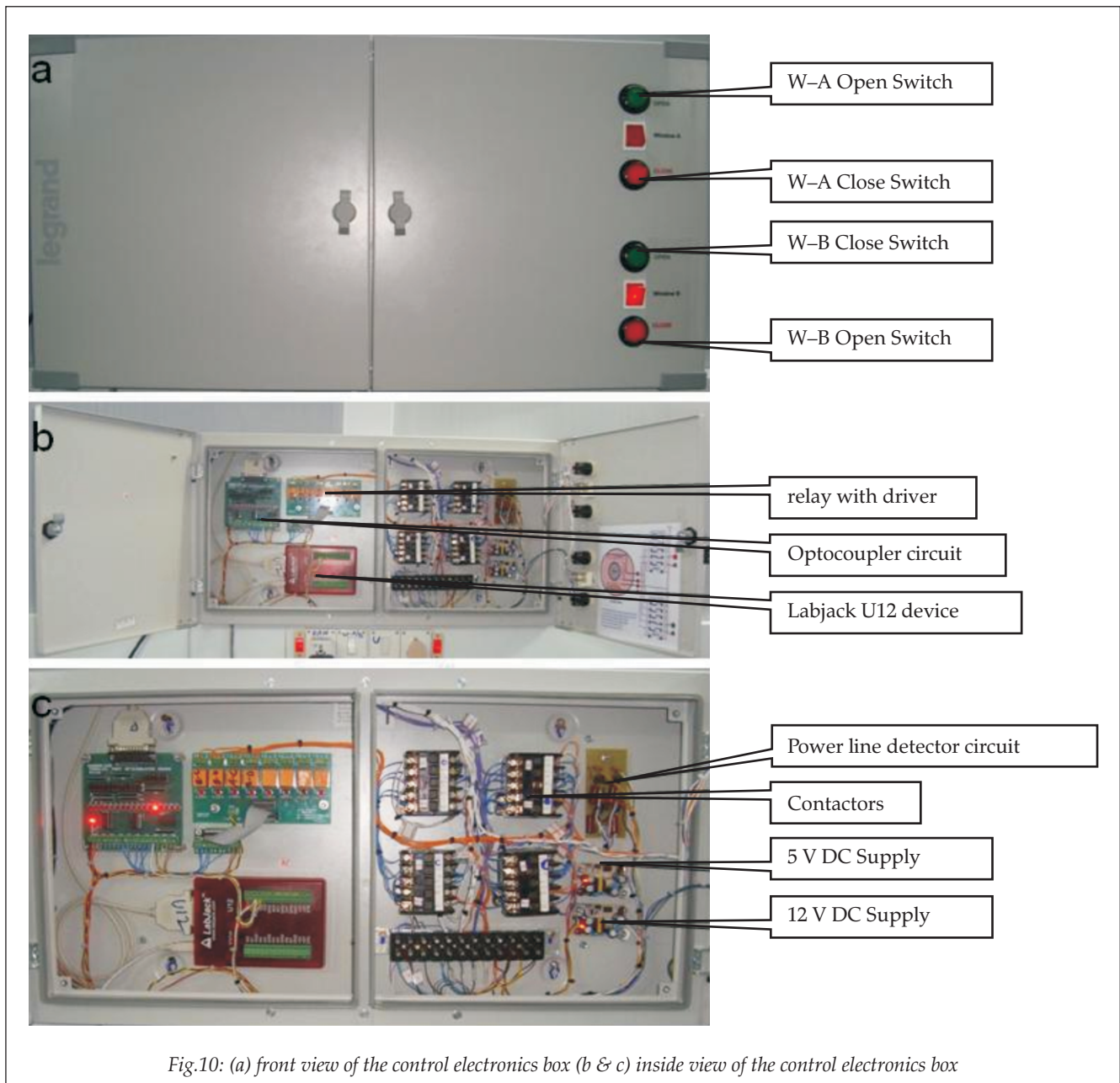


Fig.10: (a) front view of the control electronics box (b & c) inside view of the control electronics box

The AMSL lab has two identical top hung roof windows with the above discussed roof window systems. The control electronics is designed to operate two independent and identical roof window systems (window A & B). The LIDAR instrument is been operated under window B as seen in appendix B. Figure 10 shows the images of the roof window control electronics box kept inside the Aerosol Mass Spectrometer & Lidar lab. The roof window control electronics is designed for manual as well as computer operations. It consists of contactors, optocoupler circuit, relay with driver circuit, power line detector circuit, 12 V & 5 V DC power supplies, Labjack U12 device and push button switches as illustrated in figure 10.

The “Roof window application software” when initialized it reads the status of limit switches and the ultrasound distance sensor and displays the message as illustrated in appendix B. Table 5 & 6 illustrate the limit switch status and control signals for the windows (A & B) respectively. The “Roof window application software” issues the open and close command to the AC induction motor through U12 device. When the open command is issued for window B, relay #1 is activated for 100 milliseconds (ms) and it enables the contactor WA-C1. The contactor is wired such that once it is enabled; it can only be disabled when the upper limit switch is activated by the roof window B. When the window B is in open condition the upper limit switch is in normally open

Sr. No.	Limit switch address	Window A	Window B
1	11	Closed	Power OFF/Closed
2	03	Opening/Closing	Power OFF/Closed
3	07	Opened	Power OFF/Closed
4	14	Power OFF/Closed	Closed
5	12	Power OFF/Closed	Opening/Closing
6	13	Power OFF/Closed	Opened
7	10	Closed	Power ON/Closed
8	02	Opening/Closing	Power ON/Closed
9	06	Opened	Power ON/Closed
10	08	Power ON/Closed	Opening/Closing
11	09	Power ON/Closed	Opened
12	01	Opening/Closing	Opened
13	05	Opened	Opened
14	04	Opened	Opening/Closing
15	15	Power OFF/Closed	Power OFF/Closed

Table 5: Windows – limit switches address and status

In order to operate the LIDAR instrument, we need to open the roof window (manually or through computer software). The roof window is controlled through the “Roof window application software” when we are running the LIDAR instrument for real time data acquisition. The manual mode of operation is used for the routine maintenance of either LIDAR instrument or the roof window system (alignment, lubrication or testing).

“NO” state and the lower limit switch is in normally close “NC” state. When the close command is issued for window B, the relay #2 is activated for 100 ms which enables the contactor WA-C2. When the roof window B is in close condition the lower limit switch is in normally open “NO” state and the upper limit switch is normally close “NC” state.

Sr. No.	Control address	Window Status
1	008	OPEN Window A
2	032	CLOSE Window A
3	002	OPEN Window B
4	128	CLOSE Window B
5	010	OPEN Window A & B
6	160	CLOSE Window A & B

Table 6: Windows – control address and status

The software reads the limit switch status and distance sensor in order to update its status. It has been programmed to confirm the window opening or closing operation by reading continuously the varying distance sensor values within the specified limits in coordination with the limit switches status. The software is designed in such a way that if the window is opened and rain occurs, the rain detector output activates the window close operation without any delay. The system logs its activity so that if abnormal computer shutdown occurs then on the next “power on” condition it displays the window position status as an alert message.

7. Summary

An automated roof window system has been designed, developed and implemented indigenously at PRL. The window can be operated either in manual or computer mode. A 230 V AC single-phase induction motor with a worm reduction gear box is used to drive the window. The manual forward and reverse motor rotation (window opening and closing) is achieved using contactors, limit switches and push button switches. The window close and open positions are sensed by the lower and upper limit switches respectively. The GUI application software with the hardware is primarily designed and configured to rotate the motor in forward and reverse direction (window opening and closing). The software generated control command is interfaced through Labjack U12 device to the optocoupled relay driver unit. The relay triggers the contactors for the pre-defined time. The close and open positions of the window are indicated by the limit switch, which are detected using AC power line detector circuit. In order to assure the successful operation (opening and closing) of the window, an ultrasound distance sensor unit is integrated with the control electronics to read the various positions of window. The window takes approximately 23 seconds to either open or close. In the discussed work, the high speed operation of the window can be achieved using higher HP rated induction motor and high speed gear box with. The rain detector senses the rain drops and interrupts the hardware control electronics to close the window, if it is in open condition. As an application case study we have discussed the implementation of the automated roof window system at the Aerosol Mass Spectrometer & Lidar (AMSL) lab PRL. The user can configure the GUI application software as per requirement and it logs each and every user and system activity for any future references and

troubleshooting. The GUI application software in the distribution package can be made available to any user on request.

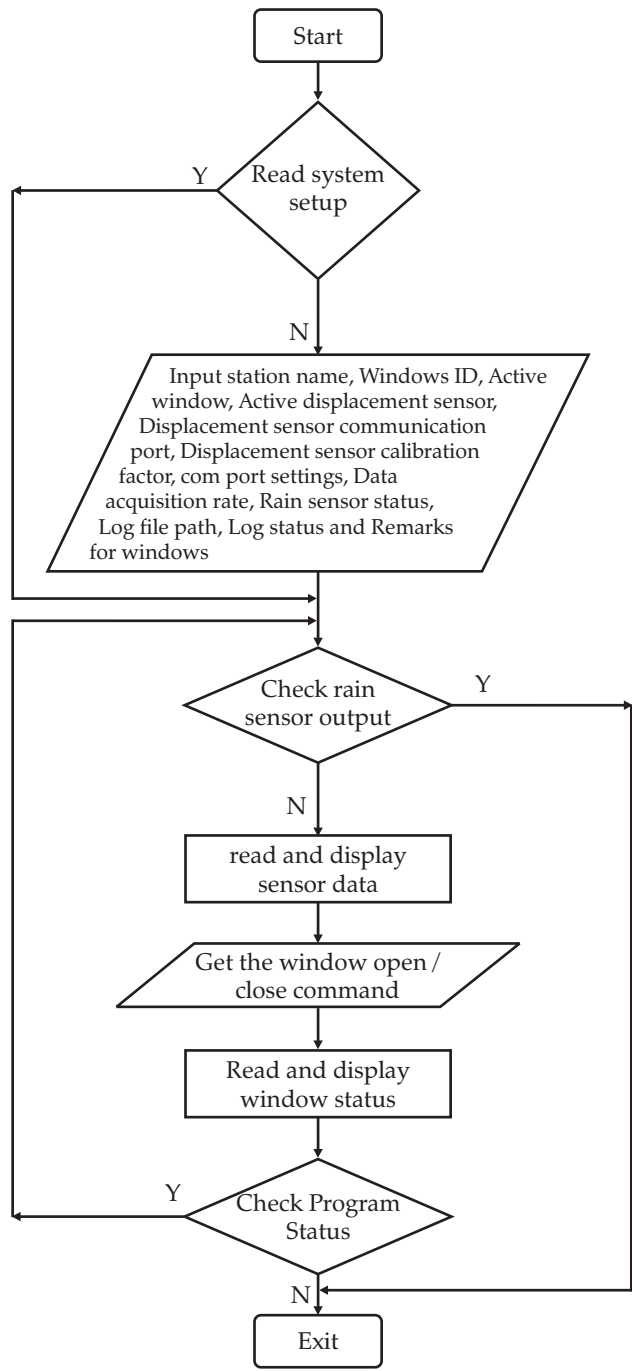
8. Acknowledgements

This work has been supported by Physical Research laboratory and the authors are thankful to the Director PRL. Authors would like to thank the PRL Workshop Department and Civil & Maintenance Division (CMD) for their assistance and support in the system integration and installation work. Thanks are also due to Mr. S. Venkataramani for his valuable inputs and suggestions during the design phase.

9. References

- [1] www.engineersedge.com/motors/induction_ac_motor.htm
- [2] www.sea.siemens.com/Contactors-and-Starters
- [3] www.labjack.com/u12
- [4] www.fairchildsemi.com/ds/MID400.pdf
- [5] www.optoinc.com/datasheets/PC817.pdf
- [6] www.rentron.com/Files/uln2803.pdf
- [7] www.rainsensors.com/docs/rg-11_instructions.pdf
- [8] www.sunrom.com/sensors/distance/ultrasonic-distance-sensor
- [9] Curland Mathew, 2000, Advanced Visual Basic 6, Addison Welsey Publications, UK
- [10] Gears and Gears Drives, 2001, Motion System Design, A145-160
- [11] Joseph Shigley & Charles R. Mischke, 2002, Mechanical Engineering Design, Mcgraw-Hill
- [12] Vladimir K. & William E., 2004, Elastic Lidar: Theory, Practice, and Analysis Methods, Wiley

Appendix: A – Flowchart



Appendix: B – GUI Screen shots



Fig.11: GUI software startup screen

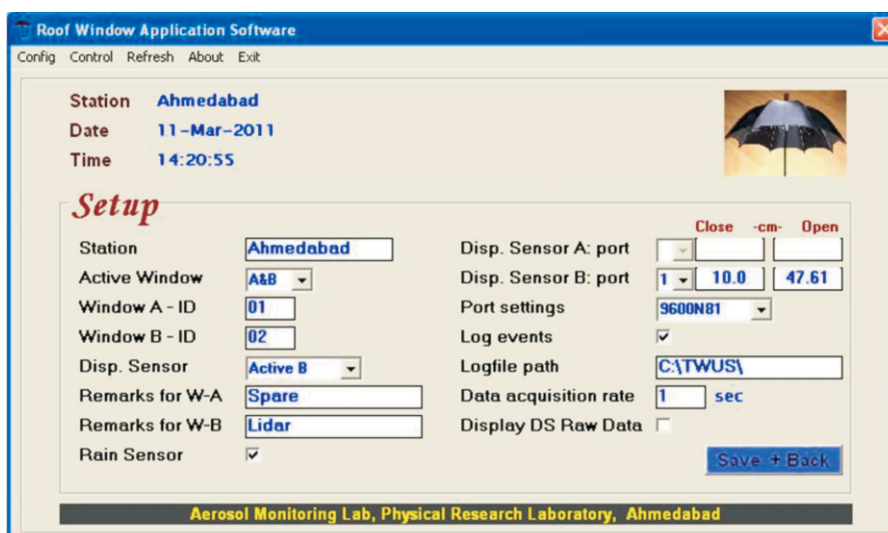


Fig.12: Software setup screen

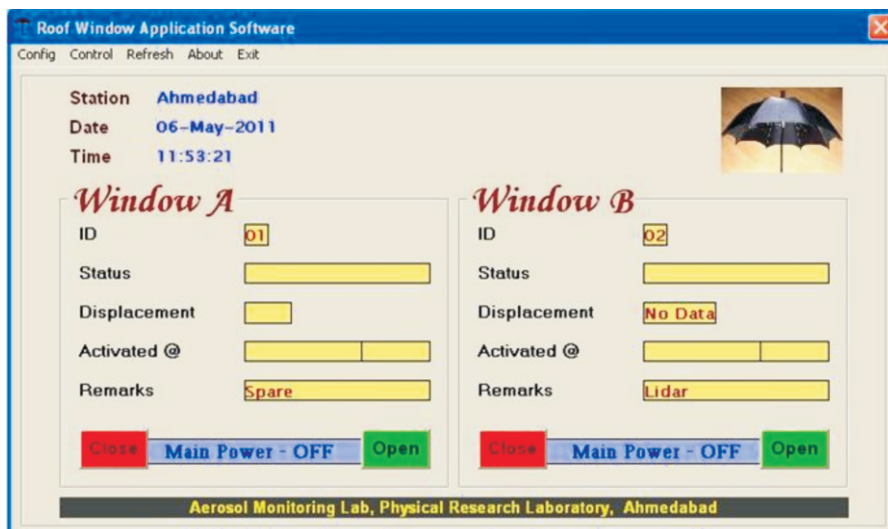


Fig.13: Windows control screen

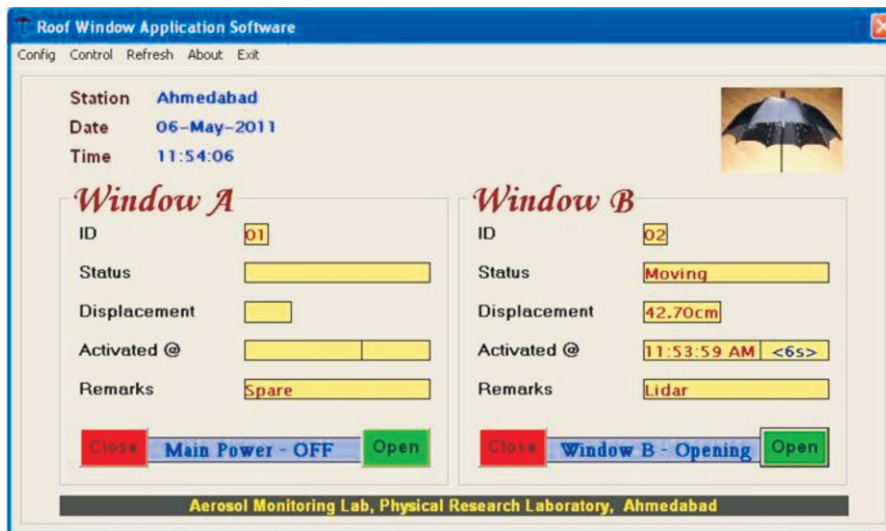


Fig.14: Window B in opening mode

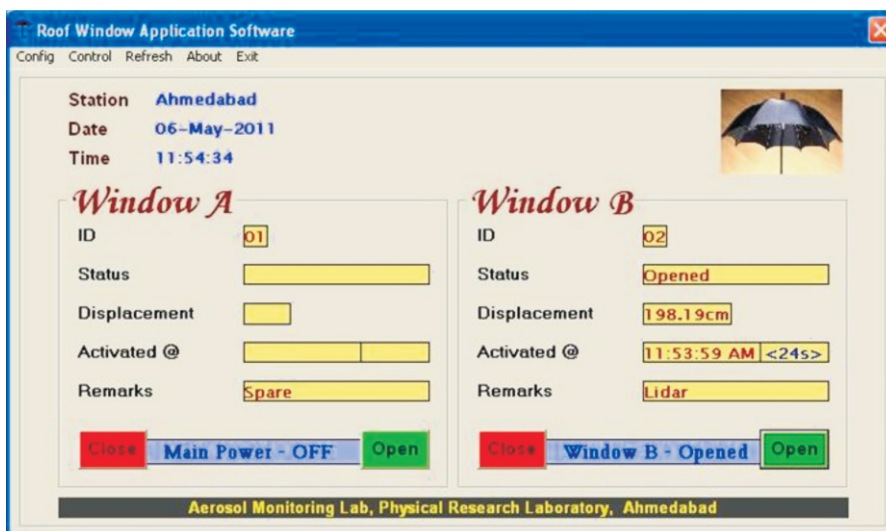


Fig.15: Window B in opened position

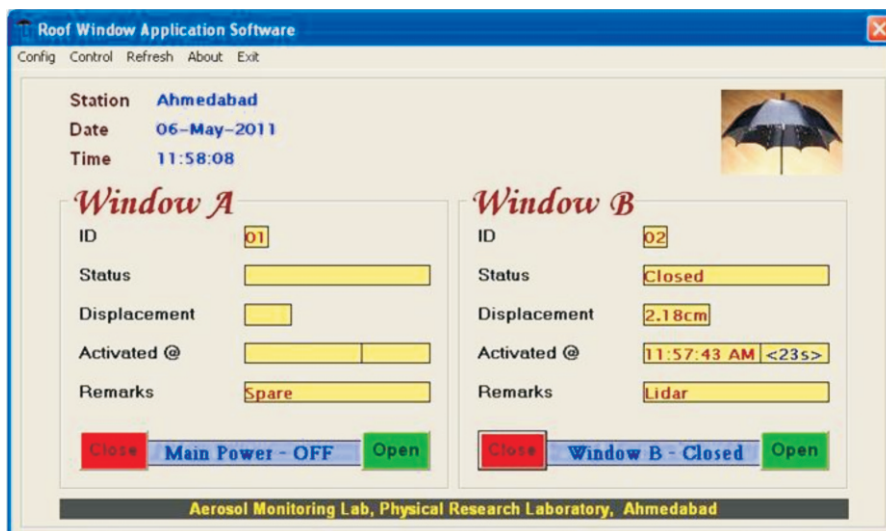


Fig.16: Window B in closing mode

Appendix: C – Roof Window Images

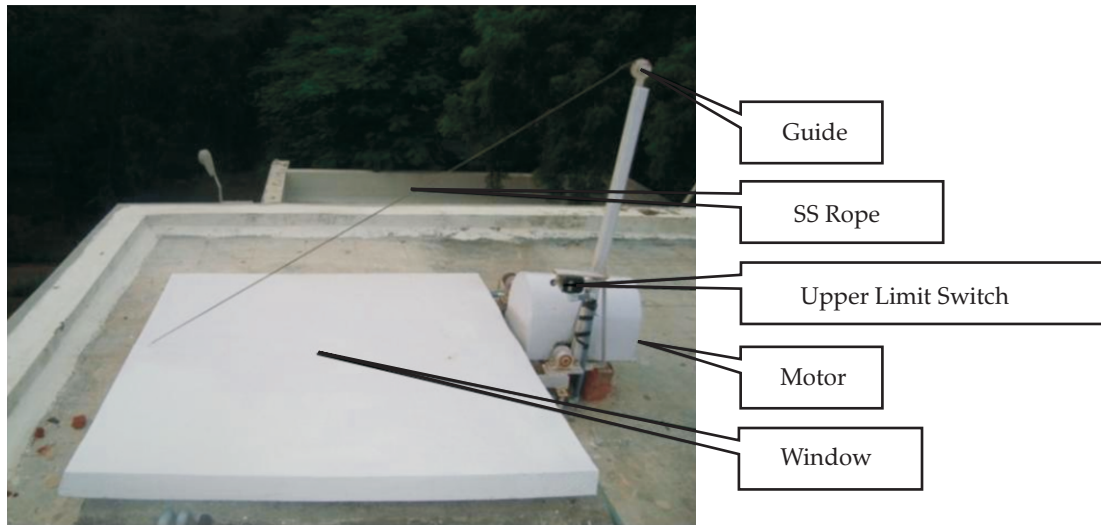


Fig.17: Roof window in close position

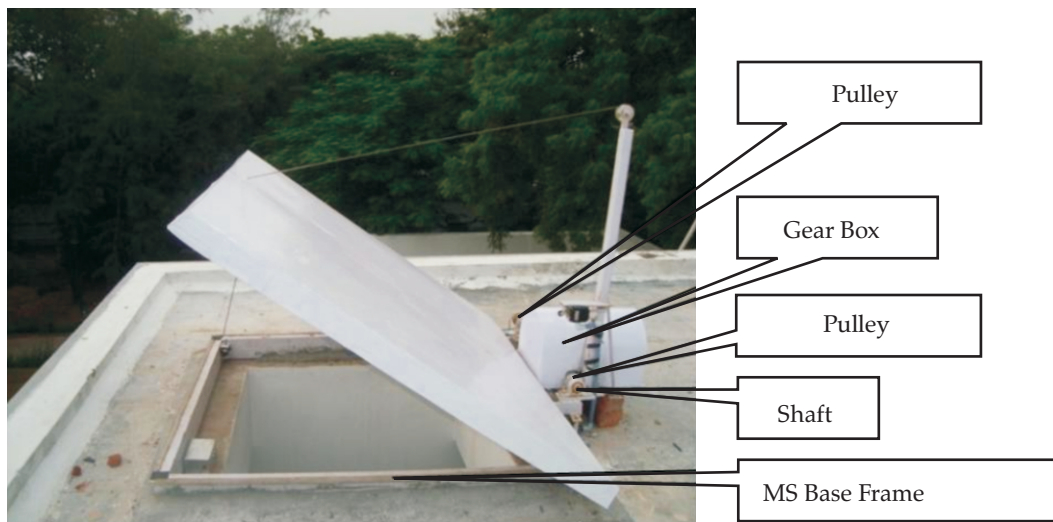


Fig.18: Roof window in half open position

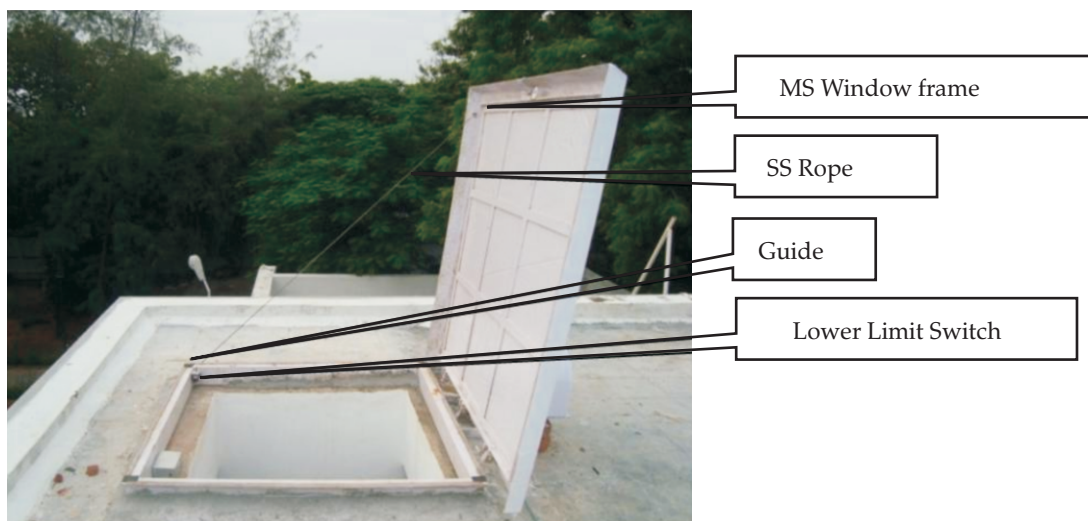


Fig.19: Roof window in open position

PRL research
encompasses
the earth
the sun
immersed in the fields
and radiations
reaching from and to
infinity,
all that man's curiosity
and intellect can reveal



पीआरएल के
अनुसंधान क्षेत्र में
समविष्ट हैं
पृथ्वी एवं
सूर्य
जो निमीलित हैं
चुंबकीय क्षेत्र एवं विकिरण में
अनंत से अनंत तक
जिन्हे प्रकट कर सकती है
मानव की जिज्ञासा एवं विचारशक्ति