ISSN 2229-5518

# Soft Switching Control for Observatory Window Shutters Movement over LAN-wifi and a GUI

Shaibal Saha, Sreejita Saha

**Abstract**— *This article illustrates design & implementation of WiFi control of pre-assigned sequential shutters movements of an astronomical observatory dome for opening and closing of the viewing window. It is done around a wifi device, controlled over LAN-WiFi, through a suitable standalone Matlab graphic user interface in low current digital CMOS remote soft switching.*

**Index Terms**— Observatory, Dome, LAN-Wifi, GUI, Matlab, Karnough Map, CMOS Logic, ESP8266.

## 1 Introduction

An astronomical dome meant for watching visible celestial objects spreaded over night-sky through an optical telescope. This requires essentially a viewing window covered with one or more shutters and those are suitably collapsible. This viewing window primarily facilitates light rays from the celestial object of interest to come in and intercepted by the telescope installed inside the dome. And the rectangular slit shaped, semicircular-curved aperture of the viewing window of the dome made to cut off as much as unwanted stray light to enter inside the dome in particular. Besides these the dome as a whole protects scientific instruments and the observers housed inside it. The above requirements are very much indicative to have a collapsible shutter to any astronomical dome window. Dome itself also needs a rotational movement in horizontal circular plane about vertical axis passing through its centre. This rotational motion of the dome enables observer to scan the sky through the viewing window.

Upon opening two shutters of the viewing window, a rectangular slit shaped aperture along with horizontal rotation of the dome enables the observer to scan through optical telescope a circular disc like zone over the night-sky. The above field of view has certain angular limit down towards horizon as shown in Figure 1a.

Thus different movements of the dome described above need number of electric motors to be fixed elsewhere on the rotating parts of the dome itself. Now, any wired electric power feed line from any external power source to either motors or installed control electronic circuits will cause hindrance to freedom of all above movements of the dome. So, a captive battery power bank is necessary to meet need of electric power along with provision of recharging the same through solar photovoltaic cells. And some sort of wireless communicationfacility is essentially needed to pass commands for movements from static observer to control electronic circuits attached to the dome for any modern astronomical observatory dome.

In view of the above, a 12v captive rechargible battery power bank along with solar photovoltaic charging unit and radio wireless communication for command control is best suited to ensure freedom of necessary of movements of the dome.

“SiriusMaxDome II”, as shown in Figure 1b, is one such standard hemispheric observatory dome [1]. It is facilitated with clockwise and anticlockwise horizontal rotational movements of the dome by means of a 12v dc powered geared motor fitted with it. This electric motor, used for actuating bi directional rotation of the dome, needs suitable commutation in feeding 12v dc power to maneuver the direction of rotation of the dome by changing the polarity of power feed line. Moreover, the command control for necessary movements of the dome must be kept in the hands of user and it should go radio wireless as explained earlier.

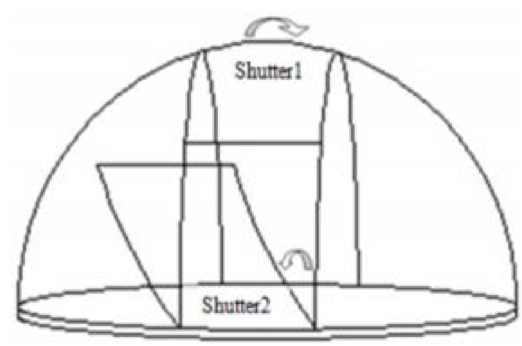



**Figure: 1a** Schamatic of Sirus dome shutters

Here, the dome has a rectangular shaped viewing window atop the dome covered with two collapsible shutters namely shutter1 and shutter2 as shown in Figure 1b. Upon actuation by electrictric motors attached to respective shutters, shutter1 slides over outside the dome thus opens half of “near 90 degree” rectangular aperture of the viewing window. Shutter2 starts flipping upon completion of opening of the first sliding shutter1. Shutter2 fitted over hinges at the horizontal-circular edge of the dome. Thus, it can move vertically outward to


- *Shaibal Saha is a Technical staff member and presently designated as Scientific Officer-D in Applied Nuclear Physics Division of Saha Institute of Nuclear Physics, Department of Atomic Energy, Govt. of India, PH-913323375345 Ext.3406, E-mail: shaibal.saha@saha.ac.in*
- *Sreejita Saha is currently pursuing her graduate degree program (B. Tech) in Applied Electronics & Instrumentation from TechnoIndia College of Technology affiliated to Maulana Abul Kalam Azad University of Technology, WB, India, PH-917059131040. E-mail: gmsreeji@gmail.com*

open the remaining “near 90 degree” half of the viewing window. Above two shutters movement completes opening of the viewing window of the dome.


**Figure: 1b** SiriusMaxDome II

At the time of closure of the viewing window, shutter2 flips first and then shutter1 starts sliding in the reverse direction to complete closing of the viewing window of the dome. So, sequence of shutters movement is first-open last-close. Now, an electronic control has to be augumented to achieve above pre-assigned sequence of movements of shutter1 and shutter2. A self guided digital electronic logic circuit as shown in Figure 2 and Figure 3, has been designed and implemented to perform the logical sequence of shutters operation both in opening and closing of the viewing window. A digital low to high controlpulse signals the control logic circuit to start opening the viewing window. The control logic circuit receives the command signal and starts opening of the window by actuating shutter1 & shutter2 in a pre assigned sequence. Similarly, a digital high to low control pulse signals the control logic circuit to start closing the viewing window. The control logic circuit itself maintains the intended sequence of shutter movements in both opening and closing operations. After passing the open/shut control signal to the control logic circuit, the electronic logic circuit completes the course of action step by step of its own untill viewing window is fully opened or closed. Four feedback control lines derived from two pair of shutter movement limit switches make senses of shutter positions while on move and cause feedbacking the informations to the control logic circuit to complete the sequence of operation.

Now, a cutting age LAN wifi solution has also been incorporated to pass on necessary open/ shut commands to the control logic circuit to initiate shutter movements. A friendly graphic user interface (GUI) over computer monitor has also been made available to interact by the user in passing above open/ shut control signal to hardware control logic circuit in Figure 10. This GUI design issues come under the perview of human computer interaction (HCI) [7].

Not only that a hardwared control switch has been privided to the users’ easy access and suitably placed at the dome end to handle any emergent situation arising upon sudden rain or stormy weather. The logic of the emergency control is designed in such a way that either in case of LAN wifi communication failure due to computer snag or power failure to server, application of it will overpower the control circuit to start moving both the shutters in closing direction immediately and finally close down the dome viewing window.

## 2 Procedure

### 2.1 TheDesign Approach

Movement of each shutter is made restricted by positioning pair of mechanical-contact limit switches at the extreme ends of fully opened and fully closed of both the shutters. All these four switches are in the state of normally closed (NC) to serve the purpose. While on move, each shutter pushes to break the contact of respective limit switch upon reaching either opening or closing limit of the move.

Two electro-mechanical DPDT (Double-Pole, Double-Throw) relays are deployed for logical commutation of 12v power feed lines to the motors according to Figure 5. Those two motors actuate respective shutters movements for opening and closing of viewing window of the dome. And motor power feed line commutation simply enables maneuvering the direction of movement of the shutters. Electronic logic control circuit receives four feedback signals of shutters limiting positions by sensing the logical voltage levels derived at the above mentioned four mechanical-contact shutter limit switches. These forms four logic control lines C, D, E & F. One logic control line“A” is obtained to pass on a digital low to high trigger for openining and high to low trigger for closing of the dome window. Pre-assigned sequential movement of shutter1 and shutter2 either of opening or closing movement is entirely guided by the digital control logic itself according to Boolean equations (i) & (ii). All of a sudden in occurance of an emergent situation such as local network failure due to various technical reasons including main power failure, another logic control line “B” also derived to constitute an emergency button placed locally at the dome end to enable users overriding any states of shutter position to initiate immediate closure of the viewing window.

Here heart of the LAN-wifi control is designed around one NodeMCU ESP8266 LuaAmica 12E development board [9]. Out of number of GPIOs (General Purpose Input Output) of ESP8266, logical state of D1 is programmed to control over LAN wifi command. To serve the purpose, ESP8266 is configured and programmed as local wifi server. The above LVTTL (Low voltage TTL logic) D1 output level is compatible to drive input of CD4000 series CMOS gates operated at 5v as shown in Table 1. But, every time ESP8266 is switched to power on, nearest AP (access point) of wifi router assigns arbitrary IP address to registered wifi devises within range of the network switch. But, it needs a fixed IP to address ESP8266, the local wifi server to pass command to any client. To solve this problem, a suitable fixed IP is assigned to ESP8266 wifi server and bind it at the network switch end. Finally, the GPIO output at D1 of ESP8266 is made available to form logic control line "A".

Above four feedback control lines namely C, D, E, F anlong with another two designated by A and B suitably converted to CMOS logic levels operated at 5v and compatible with CD4000 series gate input.

Now, two separate truth tables each for 6-input to 1-output can easily be formed such that outputs of those two truth tables make sense of driving two DPDT relays in pre-assigned sequence. Thus, corresponding shutter moves on accordingly either to open or close the viewing window of the observatory dome.

Here one issue is very important to consider judiciously the NO/NC (Normally Open/ Normally Close) and EO/EC (Energized Open /Energized Close) contacts of those two DPDT relays in feeding power with proper polarity so that upon opening of the viewing window both the relays must be kept in energized condition. Power feed lines are only disconnected by those two mechanical limit switches sensing the fully opened condition of both the shutters. Closing movement of both the shutters are done by actuating corresponding electric dc motors meeting power in reverse polarity passing through NC contacts of those relays. If the above conditions are not met, no power will be available from the NC contacts of any relays to move the shutters for viewing window to close.

Thus, while CMOS digital control circuits making sense of generating control lines for energizing two relays in pre-assigned sequence according to command inputs from the user. Iin consideration with shutter positions, two DPDT relays doing commutation of power feed lines to the dc electric motors through proper contacts and also in proper polarity.

But, actuation on emergency control button puts two relay control lines in such digital states those empower motors attached to respective shutters to roll back them in sequential moves towards closure of the dome viewing window irrespective of state of users command for open/shut or states of control lines C, D, E & F.

## 2.2 The Truth Table

To form the truth tables for two relay control outputs viz. $X_{out}$ & $Y_{out}$. There are six input variables comprising of four feedback control lines C, D, E, F and the derived control line A for the dome window OPEN/SHUT operation a, another control line B for emergency closure of the dome window. Below two Boolean equations (1) and (2) derived for $X_{out}$ and $Y_{out}$. In both the truth table, sum of products are considered for valid 1's and don't care (X) states are ignored [4].

## 2.3 Boolean Equations

$$X_{out} = A\overline{B}C\overline{D}E\overline{F} + A\overline{B}C\overline{D}EF + AB\overline{C}D\overline{E}F + ABC\overline{D}\overline{E}F + ABC\overline{D}E\overline{F} + ACC\overline{D}EF + ABCD\overline{E}F$$

$$Y_{out} = ABC\overline{D}\overline{E}F + ABC\overline{D}E\overline{F} + ABC\overline{D}EF$$

## 2.4 Karnough Map Reduction

Now, two out of six CMOS logic lines A & B forms emergency control and window open /close control line respectively. Remaining C, D, E & F lines are feedback control lines. So, it stands six variables Karnough Map to deal with [5], [6]. And C is eliminated with due consideration of judicious don't care (X) states else 1 and 0 represents logical High and Low states respectively in binary logic.

**Table.1**

| | $\bar{D}\bar{E}\bar{F}$ | $\bar{D}\bar{E}F$ | $\bar{D}EF$ | $\bar{D}E\bar{F}$ | $D\bar{E}\bar{F}$ | $D\bar{E}F$ | $DEF$ | $DE\bar{F}$ |
|---|---|---|---|---|---|---|---|---|
| $\bar{A}\bar{B}\bar{C}$ | 0 | X | X | X | X | X | X | X |
| $\bar{A}\bar{B}C$ | X | X | X | X | X | X | X | X |
| $\bar{A}BC$ | X | X | X | X | X | X | X | X |
| $\bar{A}B\bar{C}$ | 0 | X | X | X | X | X | X | X |
| $A\bar{B}\bar{C}$ | X | X | X | X | X | 0 | X | X |
| $A\bar{B}C$ | X | 0 | 1 | 1 | X | 0 | X | X |
| $ABC$ | X | 1 | 1 | 1 | X | 1 | X | X |
| $AB\bar{C}$ | X | X | X | X | X | 1 | X | X |

The above Karnough reduces Boolean equation (1) to:

$$X_{out} = E + BF \tag{3}$$

and, represented by logic gate diagram shown in Figure 2 below.

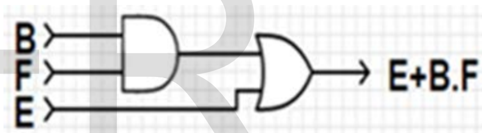



**Figure: 2** Logic gate circuit

Similarly,

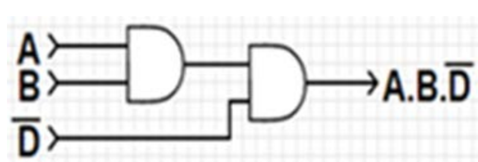
**Table.2**

| | $\bar{D}\bar{E}\bar{F}$ | $\bar{D}\bar{E}F$ | $\bar{D}EF$ | $\bar{D}E\bar{F}$ | $D\bar{E}\bar{F}$ | $D\bar{E}F$ | $DEF$ | $DE\bar{F}$ |
|---|---|---|---|---|---|---|---|---|
| $\bar{A}\bar{B}\bar{C}$ | 0 | X | X | X | X | X | X | X |
| $\bar{A}\bar{B}C$ | X | X | X | X | X | X | X | X |
| $\bar{A}BC$ | X | X | X | X | X | X | X | X |
| $\bar{A}B\bar{C}$ | 0 | X | X | X | X | X | X | X |
| $A\bar{B}\bar{C}$ | X | X | X | X | X | 0 | X | X |
| $A\bar{B}C$ | X | 0 | 0 | 0 | X | 0 | X | X |
| $ABC$ | X | 1 | 1 | 1 | X | 0 | X | X |
| $AB\bar{C}$ | X | X | X | X | X | 0 | X | X |

The above Karnough Map reduces Boolean equation (2) to:

$$Y_{out} = AB\overline{D} \tag{4}$$

and, represented by logic gate diagram shown in Figure 3 below.



(1)

(2)

**Figure: 3** Logic gate circuit

## 2.5 Mode of Operation

In the following time diagram for control logic circuit, as shown in Figure 4, ($t_3$-$t_2$) & ($t_{15}$-$t_{14}$) indicating opening & closing time of shutter1. ($t_4$-$t_3$) & ($t_{14}$-$t_{13}$) indicating opening & closing time of shutter2. And, middle white band indicating overnight viewing window open time for sky watching time including emergrncy states ($t_9$-$t_6$). The measured value of opening and closing time of shutter1 found to be ~23.7s & ~30s and that of shutter2 are ~36.3s & ~38.0s respectively. Moreover, shutter2 is very much prone to suffer dependency on air resistance while moving in particular. But, ($t_9$-$t_6$) implies sky watching time. It is much longer time compared to rief time taken by both the shutters in opening and closing altogather.

Initially, both the shutters are closed. 12v battery power is switched off. Upon switching on the 12v battery power, control lines C, E, A, B are set at low and both the outputs $X1_{out}$, $X2_{out}$ are going to logic state low. And, D, F and B are are at logic state high.

Now, initial opening of GUI application in Figure 7 maintains the control logic line "A" still in low logic state but open switch is activated to act on and shut switch is inactive. An initiation to open switch makes the control A high thus throws the $X1_{out}$ a state of logic high. A full opened shutte1 automatically initiates control line D high to low state and control line E from low to high state. This condition also puts the $X2_{out}$ also in high state. In this state both the 12v power commutation relays put on energized state and drain the battery energy continuously as long as the viewing window of the observatory remains open.This state initiates the shut soft control button at GUI in active mode leaving the open control button in inactive mode. The shut control button is now ready to accept close command upon mouse click to close the viewing window of the observatory. In this case, the shutter2 moves first and initiates the shutter1 closing movement upon its full closing. Thus,

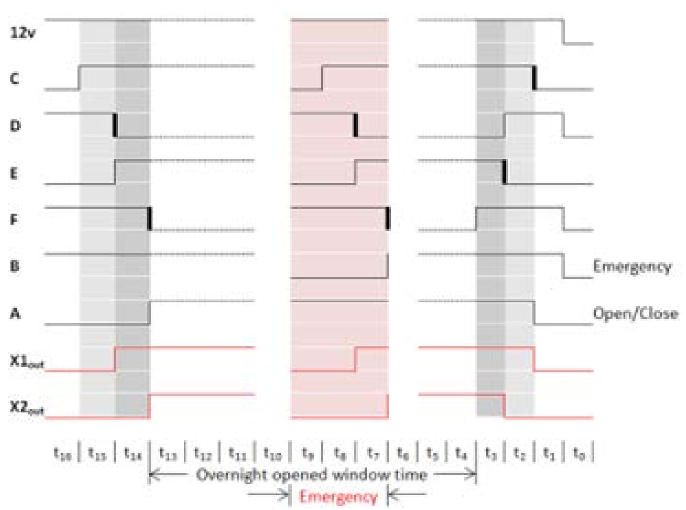



**Figure: 4** Time diagram of control circuit

when the both shutters finally closed the viewing window, both the relays come out of energized condition.

In the time diagram shown in Figure 4, a low to high switch over in logic control lines C, E while shutters are opening and high to low swich over in logic control lines D, F while shutters are closing indicated in bold vertical lines implies electromechanical contact phenomena associated with bouncing effect at two par normally closed limit switches.

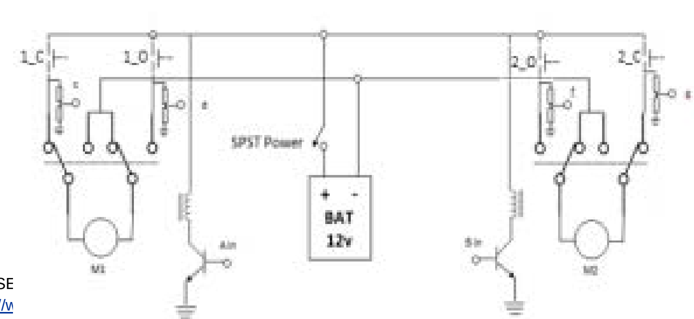
## 2.6 Contact Switch Debouncing

Contact bouncing in electro-mechanical switch causes false triggering in any digital circuit. Ringing at contacts takes about 200ms to settle down. During this 200ms settling time numerous number electrical make-break produces unwanted false triggering pulses to the inputs of digital circuits. Thus, logical operations of the control circuit fails. In this control circuit, four feedback control lines are generated from two pairs of shutter limiting switches. Out of those four only three D, E and F lines are in use and C is eliminated by Karnough simplificalton. Emergency-control-switch produces another control B to digital input. These four digital input lines must have some debouncing circuit to eliminate possible false trigerring. At first zenner positive clopper circuit were made available to change the voltage lavel of feedback signals from 12v to 3.5v levels. Then, one CMOS Schimmit-Trigger Inverter CD40106B is employed to negotiate with bouncing to the input of digital control circuit input [3].

## 2.7 Motor Drives and Commutation

The shutter1 and shutter2 movement actuators are two 12v dc geared motors. DC motors motors are free to rotate bidirectionaly upon application of voltage polarity in reverse. Here, two separate 12v dc operated double pole double throw (DPDT) relays (Omron G2R-2, 12v/5A) are employed for motor feed power line commutation suitably. The 12v dc power is feed to the respective motors for shutter1 and shutter2 from the pole contacts of the relays. Normally open (NO) contacts of those relays are connected to such polarity of 12v dc voltage source those actuat the motors in a direction of shutters move towards opening of the viewing window. And, normally close (NC) contacts to the reverse polarity so that window shutters moves towards closure of the viewing window on de-energized states of the relay coils as shown in Figure 5. This enables the user to switch off the system power without further changing the closed states of the shutters.

And both the forward and reverse direction power to the



ISSN 2229-5518

**Figure: 5** Relay commutations of motors

motors are passed through two pair limiting switches such that power to respective driving motors are get cut off by the corresponding shutters upon reaching the fully opened or closed condition. Relays are driven through two suitable Darlington pair transistor drives.

### 2.8 Emergency Button

In Figure 4 the time diagram shows an emergency control/close. A single-pole-double-throw (SPDT) toggle switch is made available at the dome end with this control to facilitate the users to close the dome shutter window at any emergent situation. It is put on highest priority so that at any state of shutter openening or opened condition and even in case of wifi failure to pass close command to the control circuit, it overpower and starts sequential closing the window shutters .

## 3 Need of Wifi

The previous version of this astronomical dome control was a manual and straight forward in nature [8]. The circuitry attached to the rotating dome was not stationery at all. So, manual control switch also go on rotating with dome. This was one drawback of the manual control. So, necessity of remote control came into picture [2]. Now-a-days in “Go digital” mood, a wired LAN control has its won limitation in this situation. So, to overcome the mobility limitation for rotating dome, a wifi control of the shutter control is made available as cutting age solution. Not only is that it always overpowered than infra-red-remote control which is a line of sight solution.
Now a wifi communication device is needed to send necessary commands to the control system as and when required. Sending command over wifi can easily be done if IP address of the server is made available.

### 3.1 Wifi Solution

NodeMCU is an open source Internet of things (IoT) platform. It includes firmware which runs on ESP8266 Wi-Fi system on chip (SoC), and hardware which is based on the ESP8266-12E [9] module. The board to be used for development is suppoted with a micro USB to serial converter CP2102 for firmware to flash with Arduino integrated development environment (IDE). Here it has been configuired to act as one wifi server. It obtains IP address over DHCP in the available wifi-LAN environment. To run it on wifi with a fixed IP, the media access control (MAC) id of ESP8366 is bind at the network switch end. ESP8288 wifi runs on 802.11/b/g/n protocol at 2.4 GHz and supports WPA/WPA2 encryption standard. One of its GPIO pin as shown in Fugure 6 is programmed to make available to control Open/Close of the dome window.

**Figure: 6** Node MCU ESP8266

### 4.1 User Intraction

Finally, an interface has to be introduced for human interaction with the control system. A command line interaction from any desktop computer connected to LAN, any laptop connected to wifi or any smart mobile phone is possible to meet the need. But, a graphic interface demonstrated the best possible way over command line interaction. So, a “Graphic User Interface” (GUI) is made available at its best form for human interaction as shown in Figure 7.


**Figure: 7** GUI for dome window control

A friendly GUI has been presentedhere as frontend to achieve universal acceptance, overcoming the technical and geographical language barrier. Most suitable metaphors are used to design the GUI in addition to English the global language of scientific communication as it stands granted. Possibilities to human err have been taken care by the golden rules of GUI design [7].

### 4.2 GUI Design Platform

Graphic user interface (GUI) is just a layer that presents the user interface to communicate with the electronic control of the shutter movement of the dome. It is more or less trivial writing in HTML code. But, here the GUI is designed purposely in Matlab R2013a windows platform. Matlab offers a powerful platform for mathematical calculations that might be a good help in processing of data. Moreover, the Matlab based GUI is made standalone through an executable file so that it can be usefull without Matlab software support at user end.

### 5.1 Use of CMOS Logic

The dome is designed by the manufacturer to run on built in captive solar rechargeable 12v battery power pack. Voltage ratings of all movement actuating motors are 12v dc. The duration of operation of the observatory dome is over night. It implies dome will be kept open for maximum long eight hours. So, foremost point of concern is low standby power consumption during dome opened hours during watching night sky because, solar charger unit remains inactive during this period. The above criterian strongly indicates use of complementary metal-oxide field effect semiconductor (CMOS) logic gate devices. For CMOS series logic gates and CD4000 series in particular, use of 12v power from battery is quiet straight forward option. But, the ambience inside the dome is not cool enough especially during day time to manage operational temperature due to excessive heat dissipation of CD4000 serieddigital logic ICs if opetated at 12v. Operation of CD4000 series digital logic ICs at 5v manages heat dissipation as wel compatible to LVTTL direct drive from Node MCU ESP8266 GPIO pin shown in Figure 6. And need not require any LVTTL to 12v CMOS logic conversion. Low current switching in CMOS devices is less prone to suffer signal to noise ratio (S/N) or cross talk issue in this low speed digital circuit.

Table1.
Logic level states

| Logic | Input | | Output | |
|---|---|---|---|---|
| 5v CMOS | 5≥ H ≥3.5 | 1.5≥ L ≥0 | 5≥ H ≥4.95 | 0.05≥ L ≥0 |
| 3.3v LVTTL | 3.3≥ H ≥2 | 0.8≥ L ≥0 | 3.3≥ H ≥2.4 | 0.4≥ L ≥0 |

H=high logic, L=low logic

### 6.1 Captive Power Stroge Consideration

Change in battery load current as shown in Figure 8, for digital gate circuit drawing ~130mA steady state upon power on indicated by phase1. Thereby a trigger “OPEN” starts opening the shutter1 through shutter2 and halts at a steady state drain current of ~202mA during the viewing window is open.

Upon triggering “OPEN” the whole automated opening phases (Phase2 & phase3) takes maximum ~60 seconds. Similarly, upon triggering “SHUT”, the whole automated closing phases (Phase5 & phase6) take atmost another ~60 seconds.

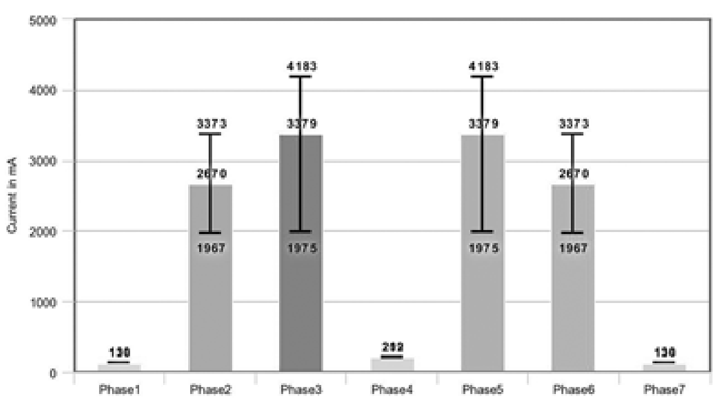



**Figure: 8** Shutter movement phases’ vs current

The above two phases take control logic gates current, relay coil current and two shutters driving motor currents one after another a minimum 1.8A to maximum 3.5A varying current. Though the above four phases are the maximum current drawing phases, duration is limited to maximum 120 seconds altogether. But, the opened window phase, indicated by phase4, is the longest duration phase and may take whole night, i.e. the sky watching hour. So, in this phase battery drain current is a matter of concern and fortunately in this phase the steady state current goes down to ~202mA. Therefore, 120 seconds dynamic, high current phases (opening and closing) consume maximum 0.133Ah battery energy and sky watching period will consume @0.202Ah/hour battery energy.

There is a 26Ah, 12v solar recharge captive battery backup installed to the control system. This implies a fully charged battery can provide power to the ideal system for 128 hours nonstop until fully exhausted. Fortunately, considering all seasonal variations, annual average sunlight time and daylight time in Kolkata (22°34′10.92″N, 88°22′10.92″E) are 07:08 hrs. and 12:00 hrs respectively.Thus sunlight will reappear beyond maximum hours of night duration to recharge the battery through solar power charging unit. So, the system is well designed for overnight uninterrupted skywatching and no shortfall of power due to over night charging vacation period. Battery will regain its charge during day time when no sky watching activity as well no window opening operation comes into picture by virtue.

### 6.2 User Operating Manual

Essentially, any instrument needs a users’ operating manual and customary to have it along with the instrument.Being the users’ operating manual, it is straight forward guide to operate the instrument from the user’s point of view. The design of the GUI plays an important role in guiding the users to operate the instrument and it is always self explanatory. Judicious selection of metaphors used in the GUI are very much users dependant. Here, the targeted users are of the highest qualifield in scientific research field. So, metaphors used in the GUI are significant and sufficient enough to self guide the users to operate/control the instrument.

Therefore, a very concise user operating manual, in the form of printed booklet, is made available with this instrument. The booklet is mainly populated with step by step computer screen shoots of the GUI operation. Only power on/ off along with emergency closing switch control are mentiond in the users operating manual. Any precautions to be taken are mentioned elsewhere in the manual.

### 6.3 Conclusion

This article is next generation automation of previously manual control one [8]. This digital logic gate controlled electronic circuit, as shown in Figure 9, to control the sequential movements of two shutters of MaxDome II observatory has been implemented at Meghnad Saha Observatory in Figure 1b, at Saha Institute of Nuclear Physics (SINP), Kolkata (22°34′10.92″N and 88°22′10.92″E). We found all the logic control lines working faithfully over time. Both the motors and the logic circuit drawing current as calculated. So the 12V main solar recharged captive battery power with 26Ah energy storage suitably supportive to the system.


**Figure: 9** Command control circuit

## ACKNOWLEDGMENT

This developmental projected was financially supported by Astro Particle Physics and Cosmology Department of Saha Institute of Nuclear Physics (SINP), Kolkata. The authors like to acknowledge Prof. Satyajit Saha, Prof. Sandip Sarkar, Prof. Debadesh Bandyopadhyay and Dr. Jishnu Basu for their continuous inspiration and necessary funding. The authors also acknowledge the LAN-wifi support from Computer Science Division, SINP.



## REFERENCES

[1] Sirius Observatories: Maxdome II (Manual), http://www.apm-siriuskuppeln.de/en/details/5/18634/download/Maxdome.pdf

[2] L. R. Sonsa, F. Morgado-Dias and P. Augusto, "Low cost automated astronomical observatory for remote operation: A requisite analysis," 2017 International Conference on Internet of Things for the Global Community (IoTGC), Funchal, 2017, pp. 1-6. Doi: 10.1109/IoTGC.2017.8008969 http://ieeexplore.ieee.org/stamp/.jsp?tp=arnumber=8008969&isnumber=8008964

[3] J. G. Ganssle: "A Guide to Debouncing" Guide to Debouncing, Ganssle Group, Baltimore, MD, US, pp.1-22, August 2004 XP002407146. Retrieved from http://www.eng.utah.edu/~cs5780/debouncing.pdf.

[4] D. P. Leach and A. P. Malvino, Digital Principles and Applications, 5th ed.: Tata McGraw-Hill Publishing Company Ltd, 1995, ch. 3, pp. 93-130.

[5] K. Halder, "Karnaugh map extended to six or more variables," Electronics Letters, vol.18, no.20, pp.868-870, September 30 1982 doi: 10.1049/el: 19820589. URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4246924&isnumber=4246915

[6] Crenshaw, Jack W. (2003), A primer on Karnaugh maps, Embedded Systems Design, Retrieved from http://www.embedded.com/columns/programmerstoolbox/16100908? Requestid = 264392.

[7] S. Saha, S. Chakraborty, “Development of GUI Based Test and Measurement Facilities for Studying Properties of MOS Devices in Clean Room Environment,” Innovations and Advances in Com- puter, Information, Systems Sciences, and Engineering,E. Khaled and S. Tarek, eds., Lecture Notes in Electrical Engineering Se- ries, vol.152,Springer New York, pp. 595-608, 2013, doi: 10.1007/978-1-4614-3535-8_50.

[8] S. Saha, “Minimal Digital Electronics Relay-Feedback Control for Sequectial Movement of Observatory Shutters”, International Journal of Scientific & Engineering Research, Volume 4, Issue 10, October-2013 1081 ISSN 2229-5518

[9] http://www.instructables.com/id/Programming-ESP8266-12E-NodeMCU-Using-Arduino-/?ALLSTEPS