Intelligent Adaptive Tunnel Lighting System

Prepared By:

Mohamed Salah Musa Idris

14673

Supervisor:

Ir. Dr. Perumal Nallagownden

Field Supervisor:

Kevin William Chiu

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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh,

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

____

Ir. Dr. Perumal A/L Nallagownden

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Mohamed Salah Musa Idris

ABSTRACT

Intelligent adaptive tunnel lighting system is a design approach in which the tunnel interior lighting system adapts to the real time roadway environment conditions. More specifically, the tunnel lighting illumination levels are adjusted based on the needs of the motorists. The level of tunnel lighting can be reduced or dimmed when the intensity of tunnel exterior -daylight- is decreased. Moreover, it can also be reduced when traffic on access road to the tunnel is absent. Dimming the luminaries to meet the minimum requirements would save on power consumption as well as maintenance costs.

The basis of this project is to develop adaptive tunnel lighting system with the purpose of providing sufficient tunnel interior luminance so that motorist can access and exit the tunnel with maximum comfort and confidence. Three levels were developed with integration of motion and light sensors. The results indicate that average of 20.51 % of power consumption can be reduced by using this system. Furthermore, LED is highly recommended to be used in the system due to its luminous efficiency and long lifecycle.

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All the thanks due to Allah, The Most Gracious and The Most Merciful for His continuous and endless blessings and guidance throughout my life and the success He granted me during this period of my educational program.

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Mohamed Salah Musa, December 2014

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Abbreviations and Nomenclatures

Abbreviation/Nomenclature	Full meaning
CIE	International Commission of Illumination
IESNA	Illumination Engineering Society of North America
SICAM	Siemens Automation Unit
AI-6300	Analogue Input Module
DI-6100	Digital Input Module
DO-6200	Digital Output Module
CP-6010	Central Processor Module
PS-6630	Power Supply Module
L_{th}	Luminance of The Threshold Zone
L_A	Luminance of The Access Zone
L_{seq}	Sequence Luminance
e-mic	Enhanced Micro-controller
I/O	Input/Output
LDR	Light Dependent Resistor
LED	Light Emitting Diode
cd/m^2	Candle per meter square
W	Watt
W/h	Watt per hour
kWh/yr	Kilo-watt hour per year

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

The contribution of tunnels and underpasses in read traffic has been recognized for long time. At the very beginning, the use of tunnels was limited but the increase in traffic resulted in extreme construction of tunnels. In the first place, efforts were concentrated on the lighting of the tunnel interior where the entrance got some additional lamps to serve as a threshold. With the increase of motorization traffic and speed, this trend was revised. Since then, the International Commission of Illumination (CIE) has established standards and fundamental theories which act as a guidance for the lighting of roads, tunnels and underpasses. The basic fundamentals of CIE are still valid and applicable for the present revisions. In fact, the findings of latest researches and the practical experience of tunnel construction concluded that there are considerable differences in some aspects between CIE and the current revision. However, these differences are major but still they are undergoing through further developments of the principles that outlined in CIE. Nowadays, the increasing interest in motorization and the improvement in transportation have not only created a need for constructing more tunnels and underpasses, but also created a demand for cost effective and interactive lighting systems. Such demands are influencing tunnel lighting designers to develop more efficient and robust systems.

Several critical elements need to be considered in implementing tunnel lighting systems in order to determine visibility. These elements are diverse and comprise both motorist and road. The motorist elements include vision ability, personal habits and age while the physical conditions of the road are directly infected by the length of tunnel, access way to it, intensity of traffic as well as the atmospheric condition.

CIE guidance classifies five zones of tunnel to take into account when designing lighting system. These zones are as shown in FIGUER 1.1:

- **Access zone**: it is the part just immediately prior entering the tunnel (in front of it). From this zone motorists should be able to detect any possible obstacles inside the tunnel.

- **Threshold zone**: it is the first part of the tunnel which is visible for motorists just before driving into the tunnel. The luminance of this zone must be in same level as the outside luminance. The approximate length of the threshold zone is equal to a safe stopping distance. The stopping distance is defined as the distance necessary to safely stop a vehicle from moving.

- **Transition zone**: it is the part locating directly after the threshold zone. The luminance level of this zone is gradually decreasing from the threshold luminance level till it reaches the luminance level of the interior zone.

- **Interior zone**: this is the zone located between transition and exit zone and often the longest in the tunnel. The luminance level of this zone is often constant.

- **Exit zone**: it is the last zone of the tunnel where the vision ability of motorist approaching the exit is adjusted in accordance with the brightness outside the tunnel during day time. The luminance level of this zone should increase gradually to the level at least same as outside the tunnel.

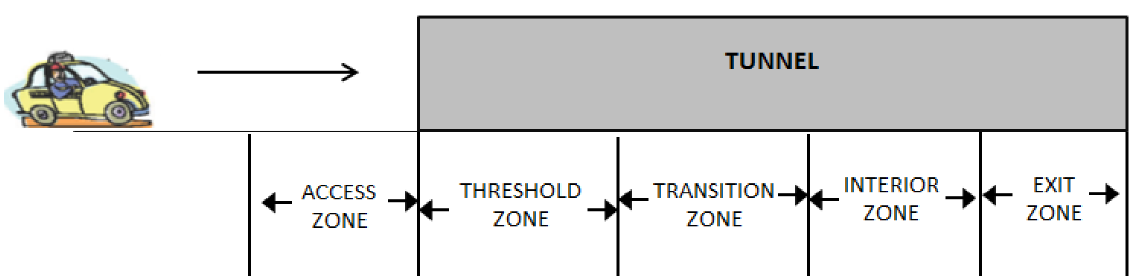

FIGURE 1.1: Tunnel Zones Topology [3]

1.2. PROBLEM STATEMENT

Sufficient light for a tunnel is absolutely different from daylight to night. At daylight, the problem of lighting and visibility are most critical due to the disability of human eye to immediately adjust to the relative darkness inside the tunnel. At night, the scenario is relatively simple and consists of providing luminance level inside the tunnel at least the same as outside the tunnel. The motorist approaching the tunnel is hardly able to detect obstacles on the road under condition of a highly illuminated exterior and a relatively dark interior (The Black Hall effect).

In fact, the human visual system is barely able to adapt to rapid reduction in illumination, such as that occurring when passing from daylight into the darkness of a tunnel; these adjustments are not instantaneous. The adaptation process takes time depending on the amplitude of the reduction. Thus, longer adaptation time is needed for greater luminance difference.

On the other hand, there is much of electric energy wastage in tunnel lighting due to its design based on the luminance level outside the tunnel. This electric energy is required to eliminate the Black Hall effect so that motorist can drive through the tunnel with maximum safety and comfort.

1.3. OBJECTIVES AND SCOPE OF THE STUDY

The main goal of this project is to design a tunnel lighting system that allows traffic to access, travel through and exit the enclose section of the tunnel with maximum comfort and safety. The approach toward achieving this goal is by adequate the luminance of the tunnel interior which enables motorist to quickly adjust to the light level and easy identify possible obstacles without speed reduction. In another word, the objectives of this project are:

- To design an intelligent tunnel lighting system which is able to automatically adjust the tunnel interior luminance level in real time so that motorist can access, travel through and exit the tunnel conveniently. The system is to be designed by using Siemens Automation Units (SICAM) with integration of light and motion sensors.
- To design an intelligent tunnel lighting system which able to reduce power consumption.

The critical matter presents in determining the threshold zone where the required luminance must be almost the same as the outside light. This will totally rely on the luminance level just prior accessing the tunnel. Therefore, it is essential to identify the luminance level prior accessing the tunnel so that the intelligent system light up the tunnel accordingly.

CHAPTER 2

LITERATURE REVIEW

Many decades ago, the concept of tunnel lighting was limited to random illumination of the tunnel interior; additional light was place at the entrance to perform as threshold. The rapid increase of urbanization and motorization raises awareness of the tunnel lighting issue and inspire specialist to establish standers and recommendations with regard to the application of tunnel lighting. Nevertheless, many problems related to tunnel lighting have been solved by the efforts of engineers engaged in the design and construction of tunnels. As a point of fact, it was proven that quite acceptable tunnel lighting installations could be designed, in spite of the fact that they did not match the CIE standards [1]. This finding doubts the relevancy of CIE recommendations. However, they are not completely relevant any more for the present situation of the late seventies and the eighties [1].

As a matter of fact, the demand of tunnel construction will definitely raise the energy consumption required to light up the tunnel. In many cases, the luminance level of the tunnel is excessive. For example, if no traffic flows into the tunnel, the luminance level could be reduced to save energy. In addition, the new lighting technologies could be used to minimize energy consumption. It enables adjustment of the light in accordance with the desirable luminance level. Traditional tunnel lamp is mainly high-pressure sodium lamp, which has the following disadvantages such as low utilization coefficient, poor color rendering, pollution to the environment, not facility to brightness adjustment, working in only a few voltage levels and not convenient for faults monitoring, repair and maintenance[6]. On the other hand, it is highly recommended to rely on LED lighting technologies in the application of tunnel lighting. At the present time, LEDs are extremely efficient light source and long lasting as well. Besides that, it is available for tunnel application with the benefit of adjusting its luminance level by controlling the current supply.

Additionally, “the installed lighting system has to be able to satisfy the safety luminance depending on: variable atmospheric and road surface conditions, and the actual traffic” [2]. The proposed lighting system in his paper has the capability of automatically adjust the luminance level inside the tunnel. The luminance level is adjusted based on input signals of the outside luminance, climate condition and traffic intensity. The evaluation of the traffic intensity and external luminance is obtained by using image processing technique of digital camera which installed in front of the tunnel entrance. Rain sensor is used to obtain the climate condition. As a matter of fact, the practice of fuzzy logic control system is considered to implement the smart lighting system. This is to overcome difficulties of obtaining mathematical equation to estimate the sufficient tunnel luminance in accordance with the input data.

2.1. THEORY

According to the CIE technical report in 2004, the threshold zone length is equivalent to a safe stopping distance and its luminance level must be constant for a distance half of stopping distance. However, it is recommended to start decreasing the luminance level of the zone gradually and linearly – starting from the second half of the stopping distance – to a level equivalent to 40% of the threshold luminance. The calculated curve in FIGURE 2.1 illustrates the appropriate drop in luminance levels for each zone. Alternatively, Illuminating Engineering Society of North America (IESNA) presents two methods of obtaining threshold zone luminance values. These methods are either from TABLE 2.1 or by applying the L_{seq} equation.

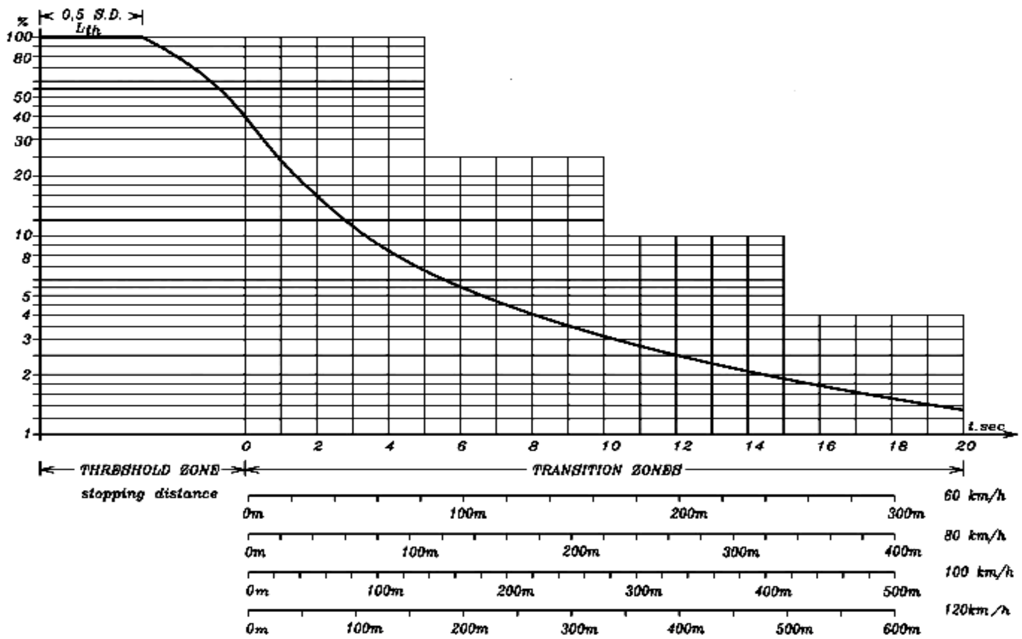

FIGURE 2.1: Recommended luminance reduction for threshold and transition zones [4]

TABLE 2.1: Threshold zone luminance for various road characteristics and approaching speeds [5]

Approach Characteristics	Traffic Speed		Traffic Direction		
	km/h	mph	North	East-West	South
			cd/m2		
Open Road	100	60	250	310	370
	80	50	220	260	320
	60	40	180	220	270
Urban Tunnel	100	60	320	280	310
	80	50	280	240	270
	60	40	230	200	220
Mountain Tunnel	100	60	230	200	200
	80	50	200	170	170
	60	40	170	140	140

The table introduces the recommended daytime luminance levels in threshold zone depending on traffic speed and direction.

Whereas, the L_{seq} calculation is based on a modified version of the Hollady Stiles formula $L_{seq} = 9.2 \sum_{i=1}^{n} \frac{E_{G/i}}{\theta_i^2}$

where: $E_{G/i}$ is illumination at the eye produced by glare source and θ_i is the angle between fixation line and glare source.

CHAPTER 3

METHODOLOGY

The methodology of implementing this project involves both software and hardware. However, prior to use software, logic architecture is needed to be design. The main function of this logic is to outline the operation of the intelligent tunnel lighting system.

As common systems, the intelligent tunnel lighting system consists of input and output. Two elements are identified as input to the system; light intensity sensor and motion detector sensor. Whereby, only the sufficient luminance level is declared as output of the system. The sensors are placed outside the tunnel; just before accessing it. The functionality of the intelligent system is simply to analysis the real time status of the sensors and base on that operates the proper luminance level of the tunnel.

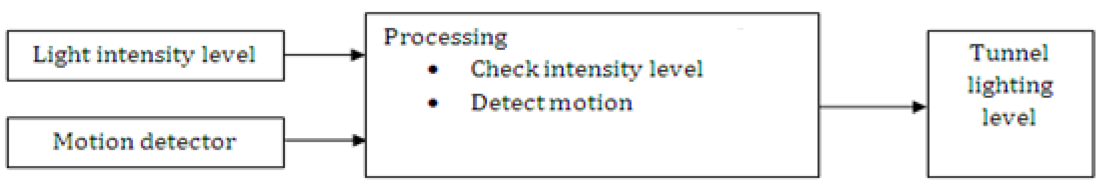

FIGURE 3.1: Functional diagram for the proposed tunnel lighting system

In another words, the methodology of implementing this project consists of three stages, namely design logic architecture, software development and hardware specifications. Design logic architecture is the function diagram of the proposed intelligent system while, the software development is program and simulate the designed logic and verify functionality. The hardware specification is to outline the component and equipment involved in the intelligent system considering sensors and controllers. Mainly, Siemens automation system (SICAM 1703) -represented by e-mic- is used to control the adaptive tunnel lighting system. The e-mic required special software to operate and execute the process associated with the proposed design. ToolBox II is the software that has been used to program the e-mic.

A. Design Logic Architecture

The designed logic starts with analyzing the status of the sensors. The signal of street intensity light is demonstrated as percentage bar. The reading of street light sensor is set into three ranges; average (from 2V to 6V), below average (less than 2V) and above average (greater than 6V) where the status of the motion detector sensor is represented as switch with motion/no motion state. In the case of no motion is detected or below average light, the tunnel lighting is set to the lowest level of luminance; level 1. Whereby, in the case of average street light, the tunnel lighting system is set to the regular level; level 2. The maximum tunnel light level is only activated in the case of above average light. The state of the tunnel lighting system is hold for definite time and then reset. The complete schematic diagram of the intelligent tunnel lighting is shown below:

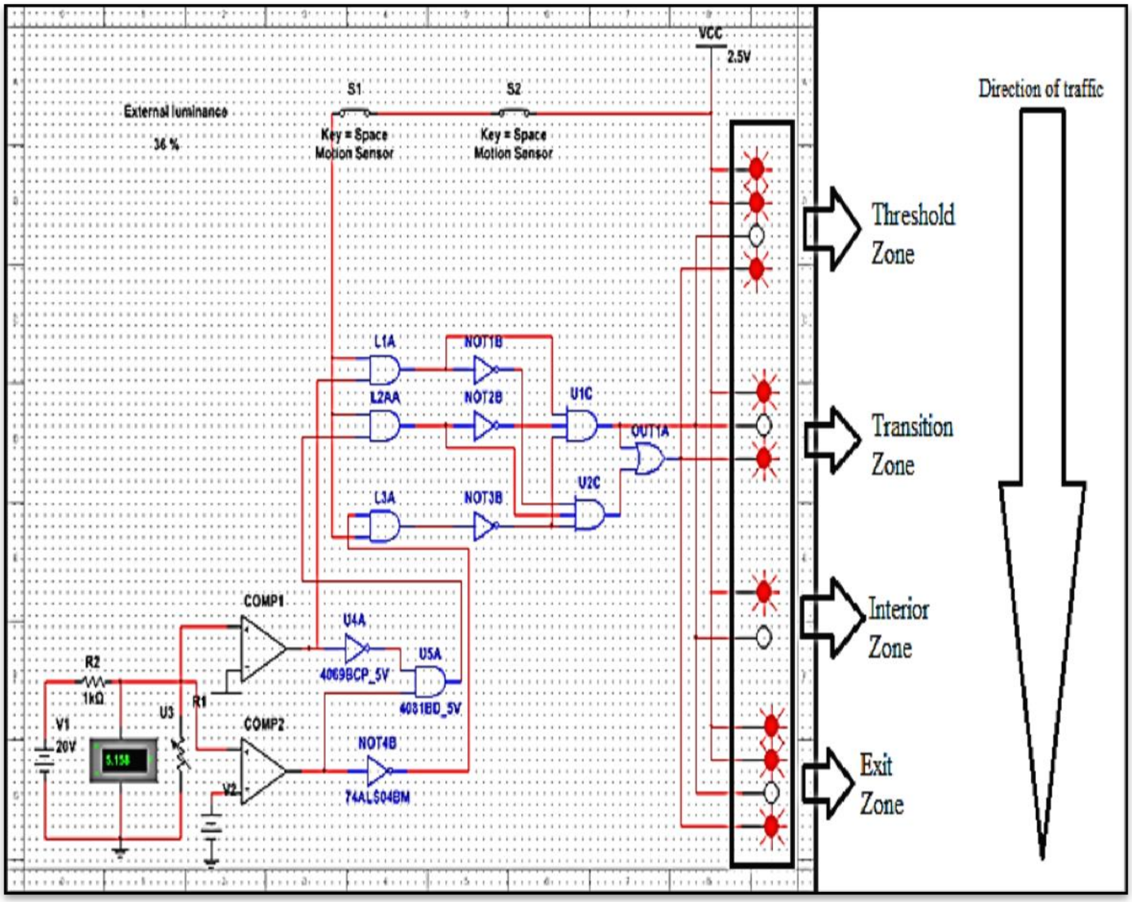

FIGURE 3.2: The schematic diagram of the intelligent system

B. Software development

Siemens automation system (SICAM 1703) -represented by e-mic- is used to control the adaptive tunnel lighting system. The e-mic required special software to operate and execute the process associated with the proposed design. ToolBox II is the software that has been used to program the e-mic.

In this software development stage, the input and output signals have been categorized. The signal form the street intensity light sensor is classified as analogue input signal. While the motion detector sensor and the tunnel lighting level signals are classified as digital input and digital output signals respectively. The input signals are injected to the logic architecture which has been constructed using several comparators and digital gates.

Prior to the design process in ToolBox II, creating a process technique is mandatory. The process technique is where all signals are created in order to manage parameters of different destination I/Os. Hence, to assign the parameters to a particular destination system, signals are grouped in **links**. Each link is assigned to a destination system and contains the specific parameters for this destination system. 1703 Peripherals is to be selected in this project.

In 1703 peripherals, three levels of process are freely addressed within the process technique plant; namely **Device**, **Signal** and **Link**. Type of higher order level is defined at the most top as shown in FIGURE 3.3.

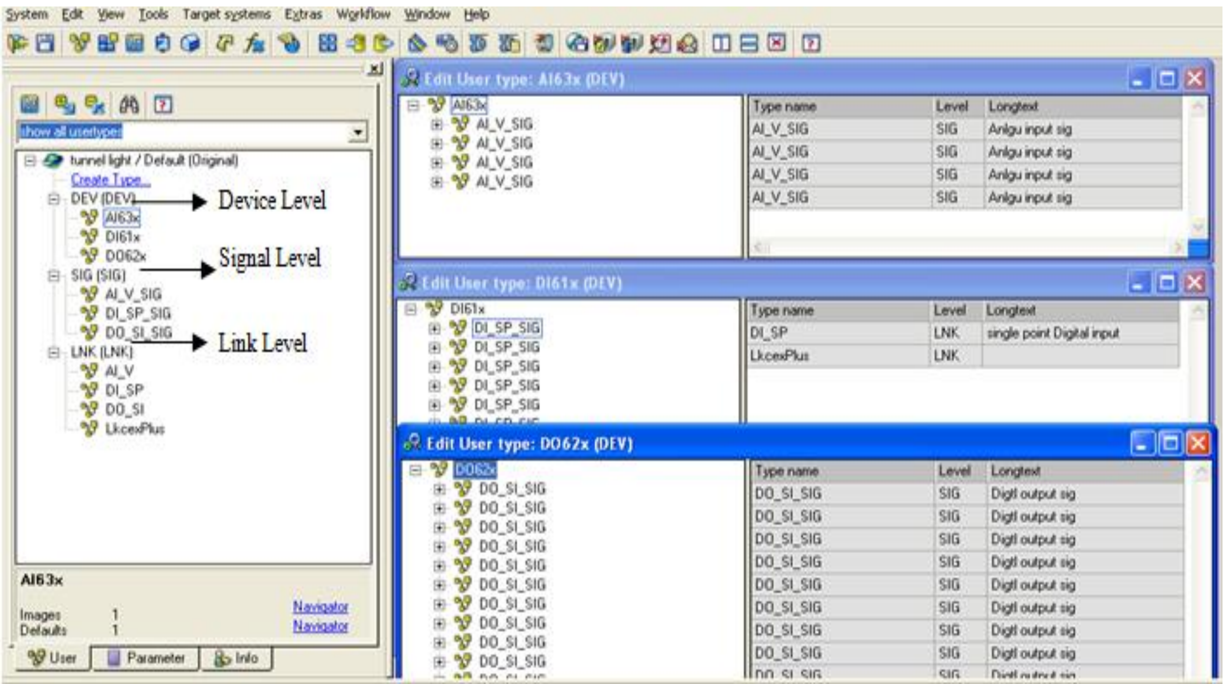

FIGURE 3.3: Levels topology of the process technique plant

In Device Level, the type of each I/O card used in the project is assigned by **Drag&Drop**, of the required I/O type from the Type Overview window into the Type Edit window. In this case, three devices are assigned in the Device Level. AI63x is assigned for the analogue input from the light sensor, DI61x is assigned for the digital input from the motion detector and DO62x is assigned for the digital output which controls the tunnel lighting level.

Subsequently, configuring the obtained process is required. System elements can be configured by **Drag&Drop** on the system-technical tree. In this case, only one element CP 6010- is to be configured. The configuration result is shown in FIGURE 3.4.

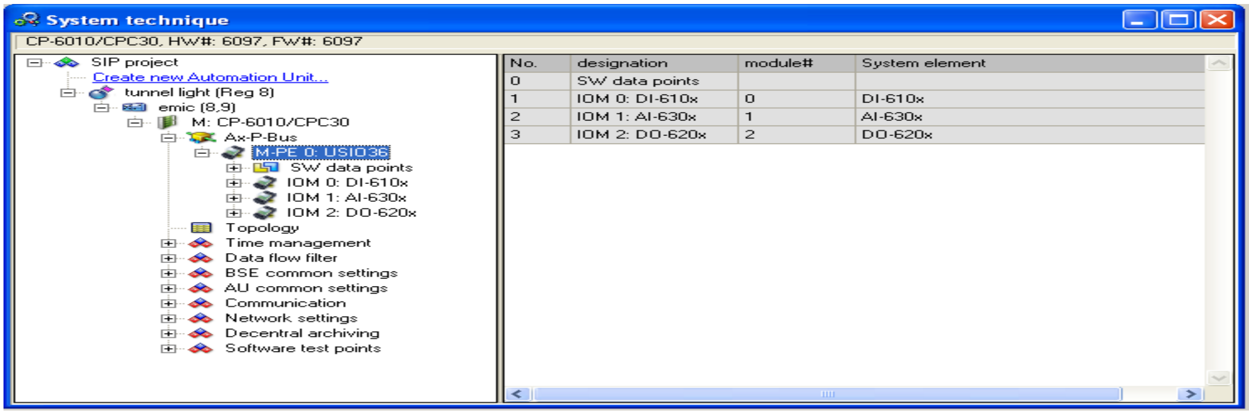

FIGURE 3.4: List of the I/O cards in the Device level

Now, user can convert the parameters into CAEx plus tool and start constructing the logic diagram. FIGURE 3.5 shows the success of conversion process. The proposed logic architecture is constructed in CAEx plus and simulation shows working principle as intended.

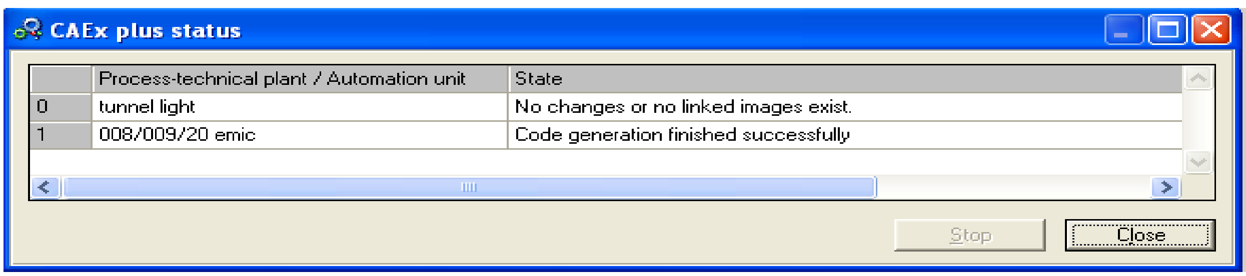

FIGURE 3.5: Code conversion into CAEx plus tool

The result of the code conversion and the complete implementation of the tunnel lighting system logic is attached in Appendix I. In general, the software starts with analyzing the status of the sensors. The reading of street light sensor is set into three ranges; average (from 2V to 6V), below average (less than 2V) and above average (greater than 6V) where the status of the motion detector sensor is set as motion/no motion state. In the case of no motion is detected or below average light, the tunnel lighting is set to the lowest level of luminance; level 1. Whereby, in the case of average street light, the tunnel lighting system is set to the regular level; level 2. The maximum tunnel light level is only activated in the case of above average light. The state of the tunnel lighting system is hold for definite time and then reset. The complete flowchart of the intelligent tunnel lighting is shown below:

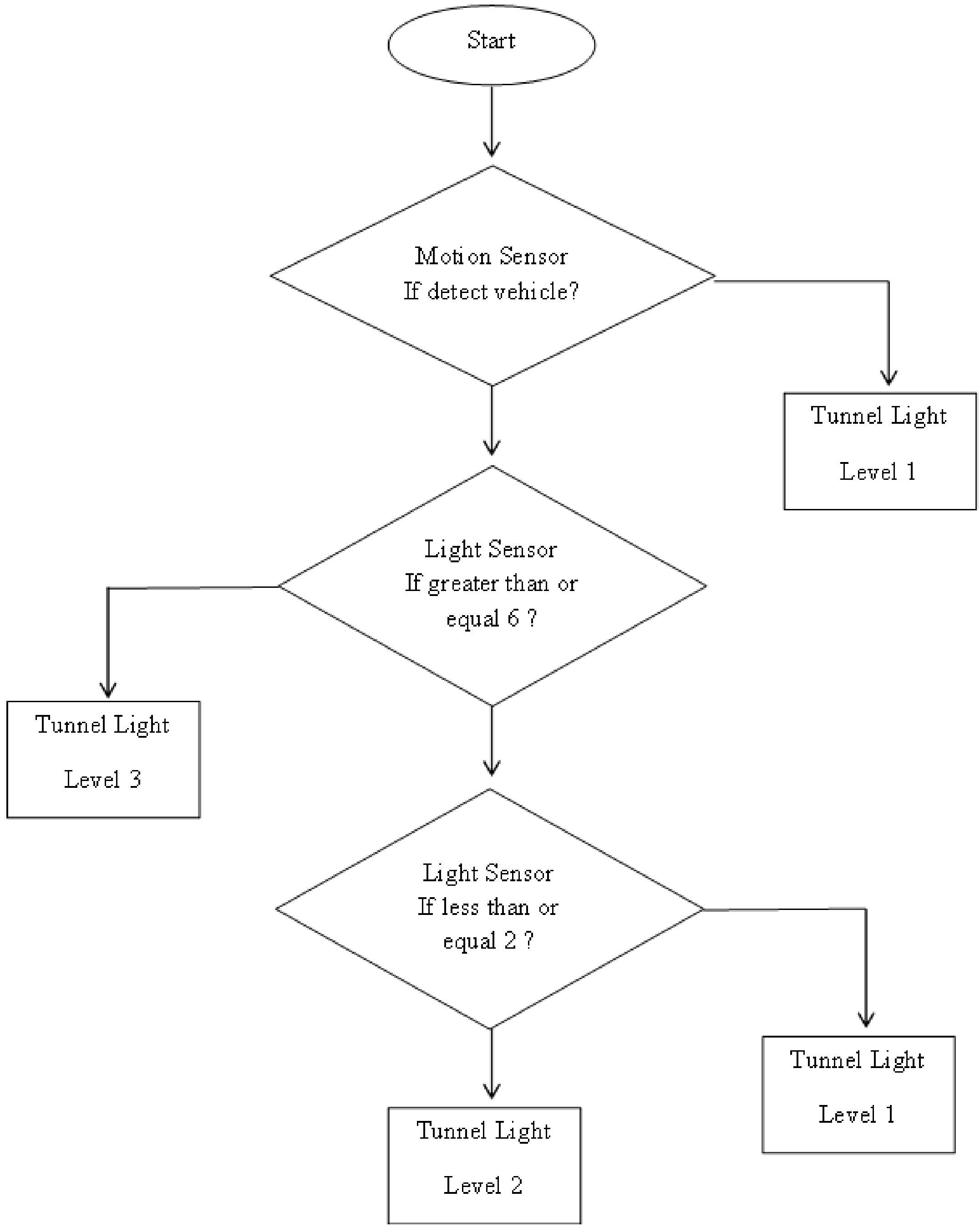

FIGURE 3.6: The operation flow chart of the proposed system

C. Hardware specification

In hardware specification, the components involve in the proposed system have been classified based on the function group; e-mic, input and output. The e-mic is the heart of the system and it performs as controller. Tow type of sensors have been used; analogue and digital sensors. The light intensity sensor is the analogue sensor and it has been connected to the AI-6300 module. The function of this sensor is to measure the intensity light level prior the tunnel and basically Light Dependent Resistor (LDR) has been used to do so. All light changes or responds are measured in volt. A resistor of 3.3 kΩ is used to control the range of voltages as the AI-3600 module operates at maximum volt of 10V.

The motion detector sensor is the digital sensor and it has been connected to the DI-6100 module. The function of this sensor is to detect the presence of vehicle and similarly, Light Dependent Resistor (LDR) has been used. The sensor will turn HIGH if vehicle is detected and will turn LOW in case of absence.

D. System working principle

This section is summary for the principle operation of the proposed design. Three levels of tunnel lighting and different input conditions are outlined. The tunnel light operates at level 3 when there is vehicle approaching the tunnel and the light intensity is above average. Whereas, level 2 is switched ON in case of presence of vehicle and the light intensity is average. Level 1 is switched ON at night or else, absence of vehicle. The status of tunnel lighting level is predefined to be reset every minute.

TABLE 3.1: Tunnel lighting levels based on the input conditions

Tunnel Lighting Level	**Condition**	
	Presence of vehicle	**Light Sensor Level**
Level 3	Yes	Above average
Level 2	Yes	Average
Level 1	Yes	Below average
	No	Do not care

3.1. GANTT CHART/KEY MILESTONE

This project is accomplished in the basis of two semesters of the final year with time frame of fourteen weeks for each semester. However, the project title has been selected and approved in the first week of the final year. Tables below show the proposed Gantt chart and key milestone for the project.

TABLE 3.2: Gantt chart and milestone for the first semester

Tasks	Week Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Topic Selection Confirmation	■	■												
Research and gathering information		■	■	■	■									
Extended proposal submission						●								
Proposal defense							■	■						
Design the logic architecture									■	■	■			
Simulation of the logic												■		
Interim draft report submission													●	
Interim report Submission														●

TABLE 0.3: Gantt chart and milestone for the second semester

Tasks	Week Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tools and software selection	■	■												
Purchasing equipment & tools			■											
Software development			■	■										
Simulation on the software					■	■								
Progress report submission							●							
Hardware and prototype development								■	■	■	■			
Pre SEDEX										●				
Submission of draft final report											●			
Dissertation submission (Soft Bound)												●		
Technical paper submission												■		
Viva													●	
Dissertation submission (Hard Bound)														●

3.2. TOOLS AND EQUIPMENT

In the process of implementing the intelligent tunnel lighting system, various devices and components were used expressly at the e-mic side and external circuitry. Software, devices and components which been used are listed below:

- ToolBox II: it is the software where all actual hardware units are employed as planning process. It enables the configuration and setting process for the project. Moreover, the actual project can be simulated to avoid errors prior hardware construction.

FIGURE 3.7: ToolBox II interface

- Master Controller Module CP-6010: it is the heart of the intelligent tunnel lighting system. It contains all the central function for processing and communication. The input and output of the system are connected to the master control module via external I/O modules. Thus, it exchanges data with the I/O module in order to execute the programmed control function. The specification sheet of this module is attached in Appendix II.

FIGURE 3.8: Master controller CP-6010

- Power Supply Module PS-6630: it is used to supply the Master Controller and I/Os modules with power. It operates with DC voltage range from 24V min to 60V max. The specification sheet of this module is attached in Appendix III.

FIGURE 3.9: Power supply module PS-6630

- Analogue Input Module AI-6300: the light sensor is connected to one of the four input slots available in this module. With referring to the data sheet, the voltage acquisition of this module is ± 10V. Only positive values have been used in this project (from 0V to 10V). The specification sheet of this module is attached in Appendix IV.

FIGURE 3.10: Analogue input module AI-6300

- Digital input Module DI-6100: the motion detector is connected to this module. It contains 2 groups of 8 binary inputs. Only one slot has been used with the motion detector. The specification sheet of this module is attached in Appendix V.

FIGURE 3.11: Digital input module DI-6100

- Digital Output Module DO-6200: the tunnel lights are connected to this module. It is essential to state that the maximum output voltage of this module is 10 V. The specification sheet of this module is attached in Appendix VI.

FIGURE 3.12: Digital output module DO-6200

- Power Supply: DC power supply is used to supply all modules since they only function on DC. The output voltage can be adjusted within range of 24DC – 40DC.
- Light Dependent Resistor (LDR).

CHAPTER 4

DISCUSSION AND RESULTS

In theory, the tunnel lighting requirements could be accessible on the basis of the fundamental formula, taking into account all the relevant characteristics of that particular tunnel. However, there is a considerable need for simplicity approach when it comes to practice, especially for a first rough design of the installation. In other word, the difficulty of obtaining the luminance of the threshold zone is overcame by implementing fuzzy logic system. From this perspective, discussion is made and results are obtained.

4.1. Hardware Calculation

It is vital to refer to the datasheet of the hardware modules used in this project. This is to ensure that the input/output values are within the capability of the module and also to avoid damages and harms to the modules. For the output module, and according to the datasheet, it supplies only DC output. Therefore, compatible LEDs with a maximum of 24 DC have been connected to this module. The DC output voltage of the module is operated by means of the external voltage supplied.

The critical concern here introduces when dealing with the inputs modules. Hence, some calculations must be taking into consideration in order to comply with the specification of hardware. These calculations are highlighted as below:

4.1.1. The Light Intensity Sensor

According to the AI-3600 module datasheet, the input voltage acquisition is ±10V. Since 24 DC is used to supply all modules, a load resistor is required to reduce the output variability of the sensor. It needs to be selected based on the luminance expected in the application. A typical voltage divider circuit is shown in FIGURE 4.1.

The light resistance of Light Dependent Resistor (LDR) is measured at both office light and dark room and found to be 5 kΩ and 500 kΩ respectively. By selecting a 3.2 kΩ load resistance, an input voltage range from 0.6V to 9.4V is produced. The calculation for the load resistance selection is derived below:

The corresponding input volt for maximum luminance is assigned to be $v_i = 9.5\,V$

The voltage divider equation is

$v_i = \frac{R_L}{R_{LDR}+R_L} v_{cc}$

Where:

v_i is the input voltage to AI-3600 module.

v_{cc} is the power supply voltage.

R_{LDR} is the measured LDR resistance at maximum brightness.

R_L is the load resistance.

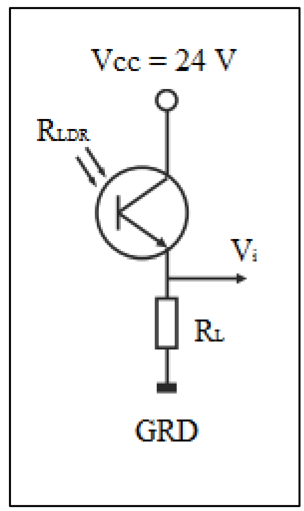

FIGURE4.1: Operating circuit for the light sensor

By substitution the values,

The equation becomes: for maximum brightness $R_{LDR} = 5k\Omega$.

$$9.5 = \frac{R_L}{5k + R_L} 24$$

Solving for R_L leads to $R_L = 3.2\ k\Omega$.

4.1.2. The Motion Detection Sensor

According to the DI-6100 module datasheet, the input status is considered logically "HIGH" when the input voltage is greater than or equal 16V. In the same way as previous, a load resistance is calculated as below:

$$v_i = \frac{R_L}{R_{LDR} + R_L} v_{cc}$$

By substitution the values, the equation becomes: for maximum brightness$R_{LDR} = 5k\Omega$.

$$16 = \frac{R_L}{5k + R_L} 24$$

Solving for R_L leads to $R_L = 10\ k\Omega$.

By selecting a 10 kΩ load resistance, the sensor status is HIGH when motion is detected and LOW is case of absence.

4.2. Data Analysis / Data Gathering

As stated earlier, the key point here presents in determining the sufficient threshold zone luminance where it must be almost the same as the outside light. All necessary values needed to determine the threshold luminance have been evaluated as following:

4.2.1. Adaptation Zone Luminance L_A

In order to determine the required luminance in the threshold zone, it is necessary to determine the luminance of the adaptation zone. As CIE recommendations, the adaptation zone luminance depends on both approaching speed of motorist and tunnel surroundings. CIE suggested three methods to determine the adaptation luminance but due to time constrain and lack of light measurement equipment, only one method is entertained. In this method, L_A value is determined on experimental correlation basis between speed and surroundings. The estimated set of values is shown in TABLE 4.1.

TABLE 4.1: Experimental adaptation luminance L_A for different surroundings and speeds [4]

Surroundings \ Approaching Speed	50 -80 km/h	80 -110 km/h
Free horizon	$\leq 5000\ cd/m^2$	$\leq 6000\ cd/m^2$
Low buildings	$\leq 4000\ cd/m^2$	$\leq 5000\ cd/m^2$
High buildings	$\leq 3000\ cd/m^2$	$\leq 4000\ cd/m^2$

It is obviously shown that high approaching speed and free horizon result in the highest adaptation luminance. Whereby, low speed and high surroundings result in the lowest adaptation luminance.

In this study, only low building surroundings are taking into account with disregarding to the approaching speed.

4.2.2. Threshold Zone Length and Luminance

It is also necessary to evaluate the length of the threshold zone in order to determine its luminance. The threshold length is approximately equal to the stopping distance which is defined as the distance necessary to safely stop a vehicle from moving. This means that the necessary luminance in the threshold zone depends on the approaching speed. Simply, the high the speed is, the long the threshold length is.

Furthermore, the approaching speed is also controlling the adjustment time of the eyes at the tunnel entrance. The higher the speed is, the less time for the eyes to adjust between adaptation zone and threshold zone.

CIE report [4] gives particular ratio between the threshold zone luminance L_{th} and the adaptation zone luminance L_A. This ration is directly proportional to the approaching speed. TABLE 4.2 gives approximated threshold zone length for various speeds and the ratio between L_{th} and L_A.

TABLE 4.2: The threshold zone length and the ratio between L_{th} and L_{A}, at various speeds [4]

Approaching Speed	Threshold Zone Length	Ratio of L_{th}/L_{A}
50 km/h	40 m	0.04
60 km/h	50 m	0.05
70 km/h	70 m	0.05
80 km/h	100 m	0.06
90 km/h	120 m	0.06
100 km/h	150 m	0.07
110 km/h	190 m	0.07

As the above table shows, the threshold zone luminance should normally be from 4% to 7% of the adaptation zone luminance.

4.2.3. Lighting Source

In designing a tunnel lighting system, the designer should take into consideration all available type of lamps. In this section, different type of lighting sources are evaluated and the most suitable source in tunnel lighting is recommended based on comparison between their service lifecycle, efficiency and power consumption. TABLE 4.3 is showing different types of lighting source used in tunnel lighting design with their luminous efficiency and service lifecycle.

TABLE 4.3: The Life cycle and luminous efficiency for different light sources

Light source	**Average lifecycle in hour**	**Lumens per Watt**
Metal halide	15000	60-100
High pressure Sodium	22000	45-120
Low pressure Sodium	17000	80-160
Incandescent	1500	20-40
Fluorescent	12000	60-100
Compact Fluorescent	14000	50-80
LED	50000	70-150

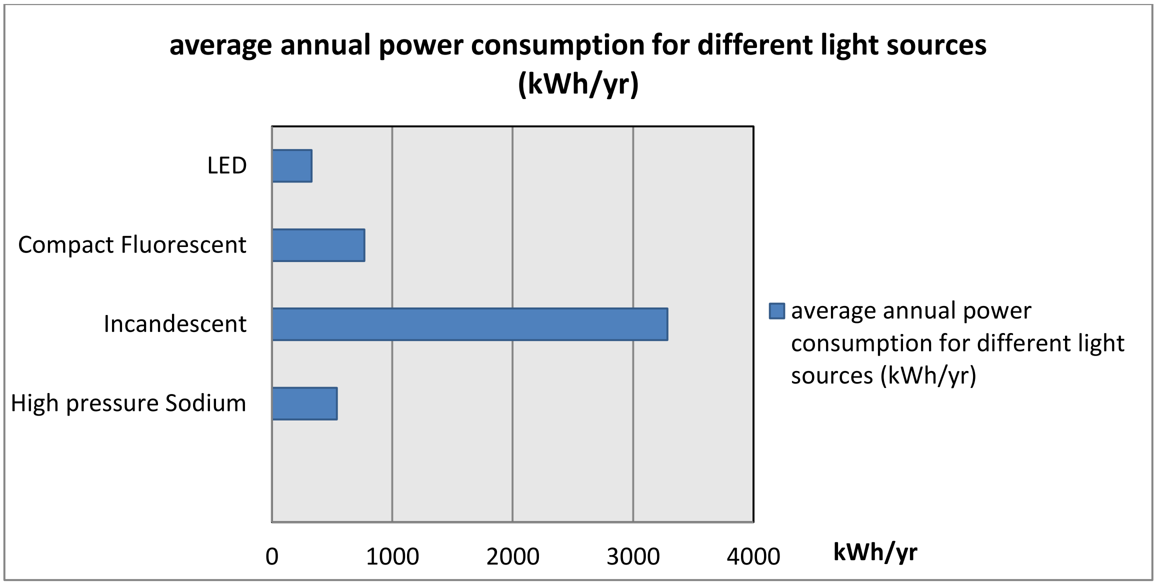

FIGURE 4.2: The average annual power consumption for different light sources [7]

From the above table, is clearly showing that incandescent light source has drawbacks. It is inefficient as it require more power to supply sufficient luminance. Moreover, its lifecycle is short which means more cost is needed for maintenance. Metal halide, Fluorescent and Compact Fluorescent light source can be categorized together as they have almost the same luminous efficiency and average lifecycle. Nevertheless, Pressure Sodium light sources produce about 38% increase in efficiency comparing to the previous sources. Alternatively, LED source is recognized for its long lifecycle comparing to other sources. Furthermore, LED has better luminous efficiency than the available light sources.

In the same perspective, the average power consumption for LED, Compact Fluorescent, Incandescent and High Pressure Sodium light sources is shown in FIGURE 4.2. It is obvious that LEDs consume much less power as compare to the other sources. LED is giving the minimum annual power consumption at 329 kWh/yr.

As a result, this makes LEDs a favorable choice as it offers the less power consumption as well as savings in maintenance cost due to its long lifecycle and energy costs.

4.3. Findings

Simple prototype has been built for demonstration and experimentation purposes. Transparent tube has been assembled to looks like a small scale tunnel. For the tunnel lighting, total of 15 LEDs is mounted on top of the tube for lighting function. However, all results and findings obtained in this section are based on the prototype construction.

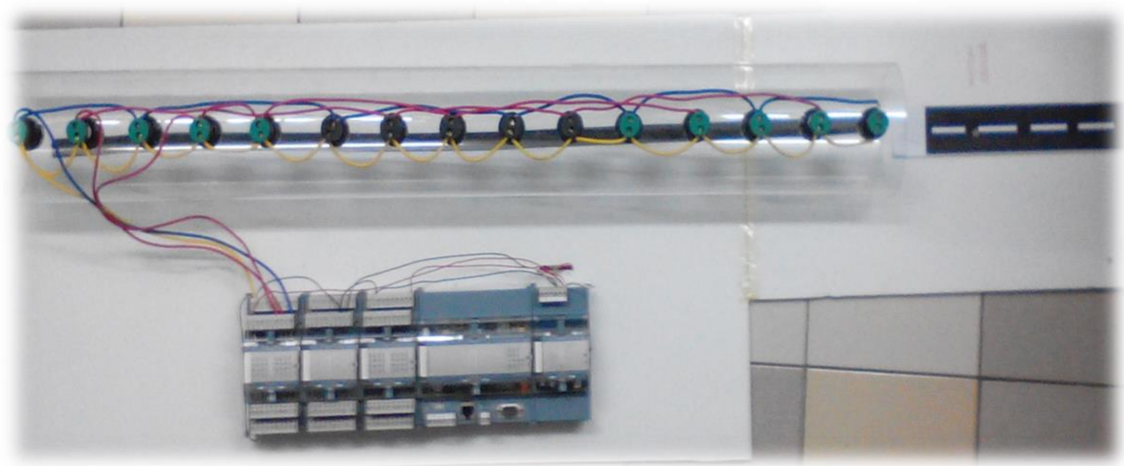

FIGURE 4.3: Prototype of the tunnel lighting system

TABLE 4.4: Power consumption result base on different conditions

Condition	Motion sensor	Light intensity level	Tunnel lighting level	Power consumption (Watt/hour)
1	HIGH	Below average	Level 1	7 W/h
2	HIGH	Average	Level 2	11W/h
3	HIGH	Above average	Level 3	15 W/h
4	LOW	-	Level 1	7 W/h

As part of experimentation, the power consumption for the three levels of the tunnel lighting is inspected and outlined in TABLE 4.4 below. The consumption of a single LED is assumed to be 1 Watt per Hour to simplify the calculation.

During level 1, the power consumption of the tunnel light is 7 W/h since only 7 LEDs lighted up. The maximum power consumption of 15 W/h is recorded at level 3 while, the power consumption for level 2 is 11 W/h.

The power consumption of the two levels which operate at daylight has been simulated for daylight time (from 7 am to 7 pm) over week. This simulation is very important to illustrate the saving in power consumption of the proposed adaptive system against non-adaptive one. The non-adaptive system is assumed to be operating only in Level 3 during the daylight time. The weather circumstances influence on the power consumption simulation of both adaptive and non-adaptive lighting systems. The tabulation of the power consumption of the systems is outlined in FIGURE 4.3.

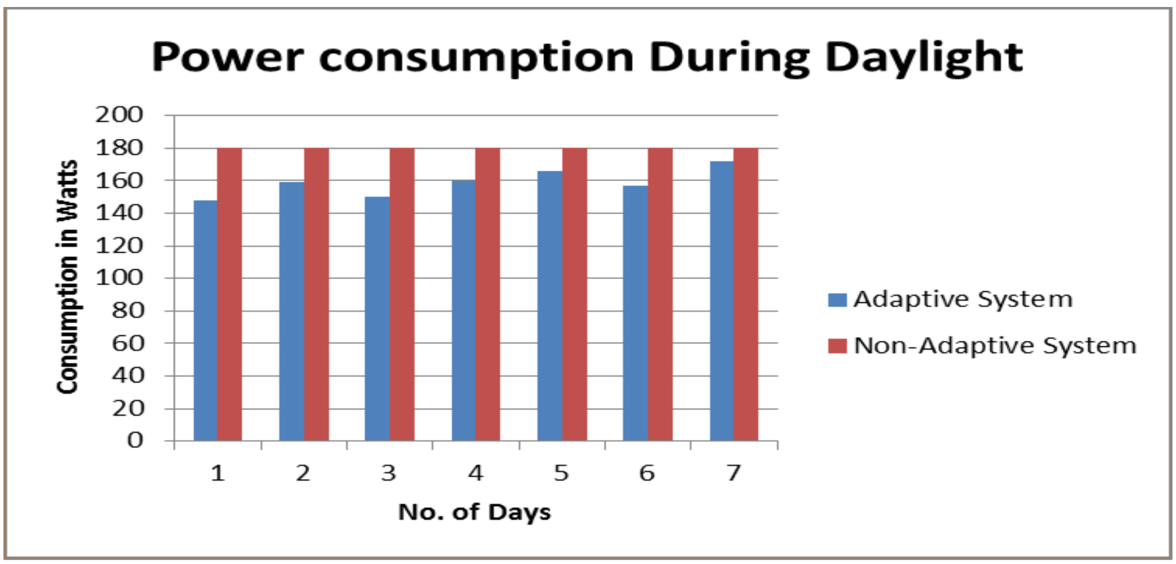

FIGURE 4.4: Power consumption of adaptive and non-adaptive tunnel lighting systems during daylight

From the above simulation result, the power consumption of the non-adaptive system during daylight time is recorded at 180 W for all seven days of the week. The recorded power consumption of the adaptive system is slightly lower due to the influence of the weather condition. The system consumed 148 W during daylight time of the first day;

159 W for the second day; 150 W for the third day; 160 W for the fourth day; 166 W for the fifth day; 157 W for the sixth day and 172 W for the last day of the week.

The percentage of power consumption reduction for the simulated result is shown in FIGURE 4.4. The maximum power saving is obtained in the first day with 24.6 % reduction. Similarly, the minimum power saving is recorded in the last day with 17.02 %. In fact, around 20.51 % of power consumption can be reduced by using the proposed adaptive tunnel lighting system.

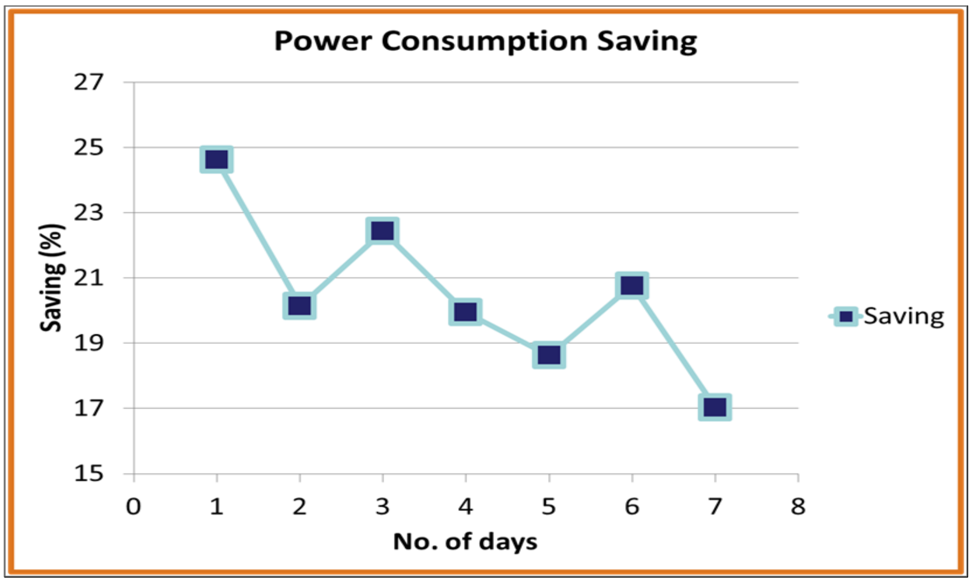

FIGURE 4.5: Percentage of the power reduction

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Several critical factors play important role in controlling the requirements for tunnel lighting implementation. These factors are diverse and involve characteristics of both motorist and the physical conditions of the road.

Five zones have been considered in designing tunnel lighting system namely; adaptive, threshold, transition, interior and exit zones. In this study, the main goal is to develop an adaptive lighting system that allows traffic to enter, pass through and exit the tunnel safely and constantly.

Siemens automation equipment mainly the e-mic has been integrated with light and motion sensors to present the design the intelligent adaptive system which allows traffic to enter, pass through and exit the tunnel safely and conveniently. As a conclusion, around 20.51 % of power consumption saving can be achieved by using the proposed adaptive tunnel lighting system. LED lighting source is highly recommended due to its low power consumption, long life cycle and high luminous efficiency.

5.2. Recommendation

- Light measurement equipment is to be used for greater accuracy in obtaining the data.
- Additional sensors –such as rain sensor- to be integrated.
- Bi-directional traffic is to be considered.

References

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[4] International Commission on Illumination (CIE88: 2004), "Technical Report for Lighting of Road, Tunnels and Underpasses"

[5] Illumination Engineering Society of North America (IESNA 2010), "American National Standard Practice for Tunnel Lighting"

[6] H. Yi, L. Changbin, W. Aiguo (2012), "LED Lighting Control System in Tunnel Based on Intelligent Illumination curve" the Fifth International Conference on Intelligent Computation Technology and Automation. pp 698-701

[7] http://www.designrecycleinc.com/led%20comp%20chart.html

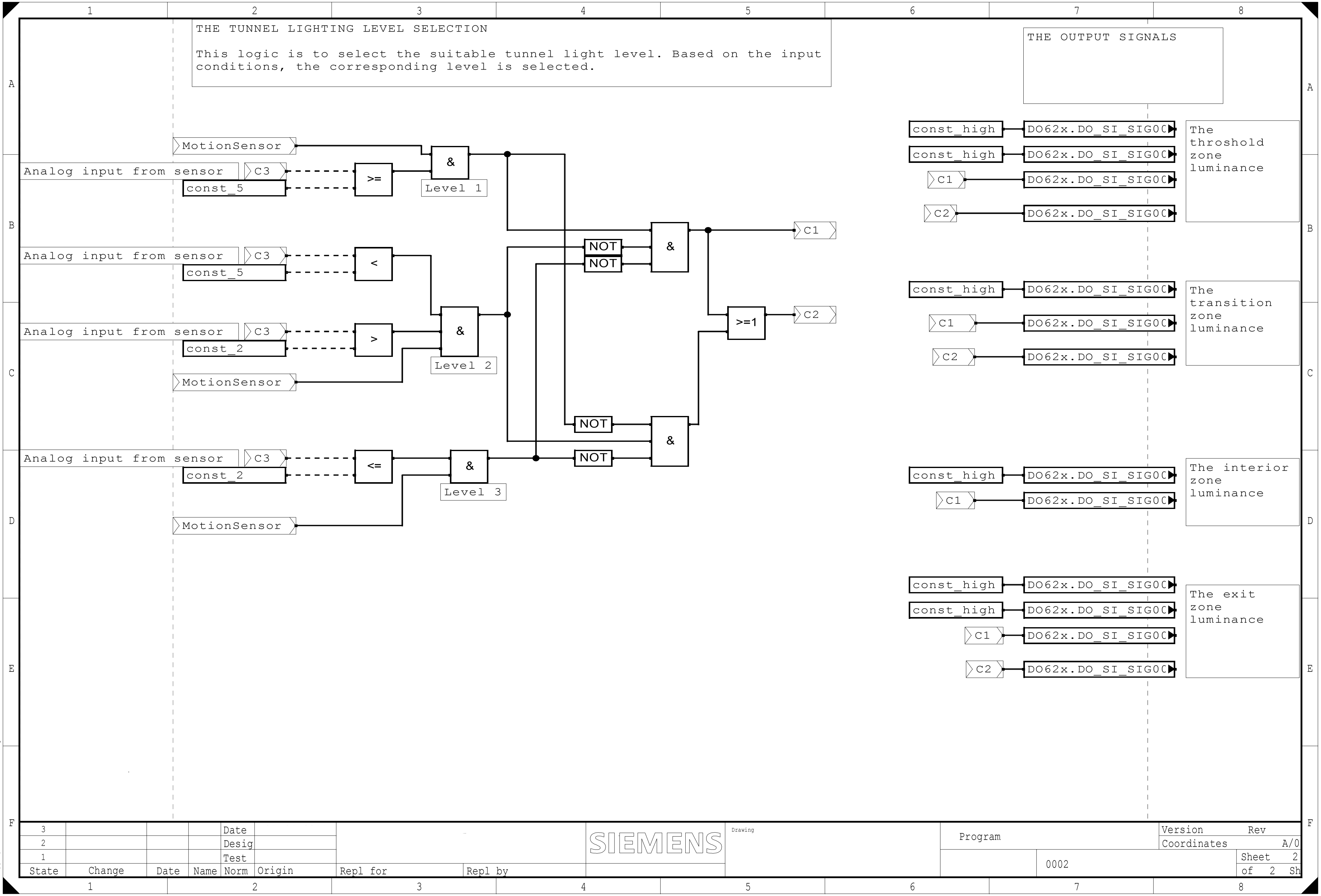
[8] TM 1703 Automation System, CP-60xx/CPC60, System Manual. SIEMENS.

[9] ToolBox II CAEx plus User Manual.

APPENDIXES

Appendix I

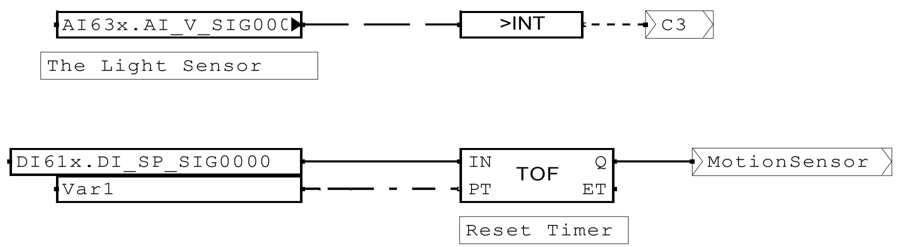
Logic implementation in CEAx tool



THE TUNNEL LIGHTING LEVEL SELECTION
This logic is to select the suitable tunnel light level. Based on the input conditions, the corresponding level is selected.
MotionSensor
Analog input from sensor
C3
const_5
>=
&
Level 1
Analog input from sensor
C3
const_5
<
Analog input from sensor
C3
const_2
>
&
Level 2
MotionSensor
Analog input from sensor
C3
const_2
<=
&
Level 3
MotionSensor
NOT
NOT
&
NOT
NOT
&
>=1
C1
C2
THE OUTPUT SIGNALS
const_high
DO62x.DO_SI_SIG0C
C1
C2
The throshold zone luminance
The transition zone luminance
The interior zone luminance
The exit zone luminance
State
Change
Date
Name
Norm
Origin
Date
Desig
Test
Repl for
Repl by
SIEMENS
Drawing
Program
0002
Version
Rev
Coordinates
A/0
Sheet 2
of 2 Sh

THE INPUT SIGNALS

This side shows both
1) The analogue input "from light sensor"
2) The digital input "from motion detector"



State	Change	Date	Name		
3				Date	
2				Desig	
1				Test	
				Norm	Origin

Repl for | Repl by

SIEMENS

Drawing

Program

0001

Version | Rev
Coordinates | (A)/0
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of 2 Sh

Appendix II

Specification sheets for the central processer module

CP-6010

6.2 Master Control Module

6.2.1 CP-6010

Processor and Memory	
Clock pulse frequency	Core clock approx. 400 MHz System clock approx. 133 MHz
Accuracy CPU clock pulse	3,5 p/min
Free run accuracy	12,6 ms/h
Program memory	Flash-PROM 2 MB (parallel connected)
Main memory	SDRAM 8 MB
Local non-volatile memory	FRAM 64 KBit (serial connected)
Changeable non-volatile memory	SD card up to 2 GB
Max. number of data points	500 (sum of process images over all 3 interfaces)
Memory for application program	128 kB, thereof 4 kB temporary memory for variables
Number of variables for application program	512 variables possible, thereof 256 Bytes non-volatile (variables: BOOL = 1 Bit, DINT = 4 Byte, REAL = 4 Byte)
Program sampling	• cyclically 10…2000 ms (settable raster 1 ms) • spontaneous (settable; run not based on interrupt)
Acquisition raster of I/O modules	10 ms
Decentralized archive	Recording raster for measured values 1, 2, 3, 5, 10, **15**, 30, 60 min, settable
	max. message length of a segment 1…200 Byte, settable
	Memory configuration, settable 10 files of 1000 records each (= 10000 records) 20 files of 500 records each (= 10000 records) 50 files of 400 records each (= 20000 records) 80 files of 450 records each (= 36000 records) 100 files of 100 records each (= 10000 records) 100 files of 25 records each (= 2500 records) 200 files of 50 records each (= 10000 records) 200 files of 25 records each (= 5000 records)
Communication	
Ethernet/LAN interface	• Ethernet acc. to IEEE 802.3 (10Base-T or 100Base-TX) • Galvanically insulated • ESD protection • Message transmission acc. to IEC 60870-5-104 • Transmission rate 10 Mbit/s or 100 Mbit/s • Half duplex or full duplex • Auto-MDI • Time synchronization via NTP server • Sub station function • Line length 0…100 m

Communication		
serial interface		• Unbalanced interchange circuit EIA-232 (level acc. to V.28) • Galvanically not insulated • ESD protection • Message transmission acc. to IEC 60870-5-101/-103 • Transmission rate up to 19,2 kBit/s (depending on modem) • Time synchronization
serial interface		• Balanced interchange circuit EIA-485 • Galvanically insulated • ESD protection • Message transmission acc. to IEC 60870-5-101/-103 • Transmission rate up to 115,2 kBit/s (depending on modem)
Power supply		
Power supply via TM bus		Input: 5.1 VDC, looped-through to max. 8 I/O modules Power consumption 1.2 W
Internal operating voltage		TM bus voltage 5 V 3.3 VDC Core voltage 0.8…1.2 VDC, regulated by CPU
Modem supply		Alternatively one of the following voltages: • De-energized (for reset of modem) • 5 VDC (PS-663x) • 10 VDC (PS-663x) • Supply via connection X4 (e.g. 12 VDC/2.5 A for TP radio modem) Wiring dimensioned for 30 VDC_{max}, 9 VDC_{min}, 3 A_{max} • Voltage range operation 12 V: 9…15 VDC Voltage range operation 24 V: 18…30 VDC
Mechanics and Connectors		
Ethernet/LAN interface	X1	RJ45 socket connector 8-pole (IEC 603.7)
EIA-232 interface	X2	Connection D-SUB 9-pole, male (DIN 41652)
EIA-485 interface	X3	Screw terminal 6-pole with shield interception
Supply for external data communications equipment	X4	Screw terminal 2-pole
TM bus	X5	Connection 5-pole to power supply module
TM bus	X6	Connection 5-pole to I/O modules
Configuration switch	S1	DIP switch for the configuration of X3 • 4-wire, no termination resistance • 4-wire, with termination resistance • 2-wire, no termination resistance • 2-wire, with termination resistance
Terminals		Removable screw terminals (grid size 5.08)
Dimensions		131 x 126 x 73 mm (L x W x H, dimensions w/o DIN rail)
Weight		Approx. 280 g

Appendix III

Specification sheets for the power supply module

PS-6630

3.2. Power Supply Module PS-6630

3.2.1. Features and Functions

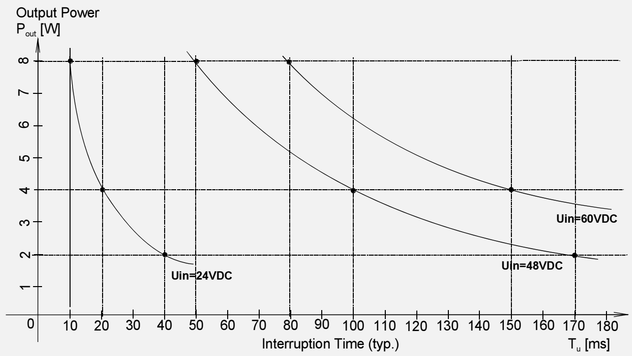
The module PS-6630 is used to supply the front-end of the series CP-6020 and CP-6040 with up to 8 peripheral modules and one external modem.

Power supply module

- Input voltage 24 .. 60 VDC
- System voltage output U1 5.1 VDC, max. 8 W
- System voltage output U2 switchable
  - 5.2 VDC, max. 2.5 W or
  - 10 VDC, max. 2.5 W
- Environmental conditions according to EMC+
- Removable screw terminals
- Function indication via LED
- Supervision of the output voltage
- Can be connected in parallel for redundancy

3.2.2. View

3.2.3. Technical Specifications

Power Supply			
Operating voltage	18…78 VDC The voltage is supplied via terminals		
Output voltages	System voltage outpouts		
system internal	**U1**	5.15 VDC ±2%	• TM 1703 ACP • TM 1703 mic • Interface modules
for external modem 2)	**U2** switchable 1)	5.1…5.4 VDC 9…10 VDC	• TM 1703 mic (CP-6020/CPC60 only)
Output power P_{U1}	$P_{U1,min}$ $P_{U1,max}$	$8.0\ W - 1.25 * P_{U2,max}$ 8.0 W (at $P_{U2} = 0$ W)	
Output power P_{U2}	$P_{U2,max}$	2.5 W	
Output total power	$P_{U1+U2,max}$ $P_{U1+U2,peak}$	8.0 W 9.0 W	
Efficiency	$\eta_{U1} = P_{U1}/P_{in}$ $\eta_{U2} = P_{U2}/P_{in}$	approx. 65% approx. 60%	
Power consumption $P_{in} = P_{U1}/\eta_{U1} + P_{U2}/\eta_{U2}$	$P_{in,max}$ $P_{in,peak}$	12.3 W 13.8 W	
Inrush peak current	8A 40A	at 18 VDC at 78 VDC	600 µs 600 µs
Guaranteed interruption time			
Reverse voltage protection	Yes		
Overload protection	No 3)		
Short-circuit protection	No 3)		
Can be connected in parallel	Yes (for redundancy, not to increase power)		
Fault Output	Potential free output In case of fault the OptoMOS relay becomes highly resistive		
Maximum switching voltage	350 VAC, VDC		
Maximum output current	120 mA permanent On Resistance 35 Ω		
Maximum short-time current	350 mA for 10 ms		

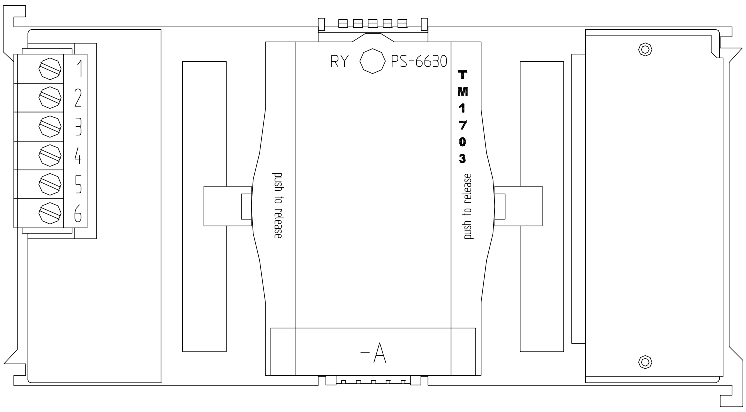
1) switching to the higher voltage is induced exclusively by CP-6020/CPC60 and depends on its parameter setting; without switching, only the lower voltage is available

2) via DTR circuit of the CP-6020 master control module's serial interface

3) Internal fuse is blown, change by authorized personnel only

3.2.7. Pin Assignment and Display

The supply voltage must be connected to two 10-pin screw terminals. The pin assignment of the connectors is described in the following table.



Power Supply 24-60VDC

4C6I1025.DWG

pin	signal
1	PWR+
2	PWR-
3	n.c.
4	n.c.
5	OUT D00 N/O
6	OUT D00 COM

4C6I1025.DWG

PWR+/- . . . . input voltage (power supply)
n.c. . . . . not connected
OUT D00 N/O . . . . monitoring normally open contact
OUT D00 COM . . . . monitoring common contact
RY . . . . Ready LED, output voltage +5VDC available

4C6I1025.DWG

Appendix IV

Specification sheets for the analogue input module

AI-6300

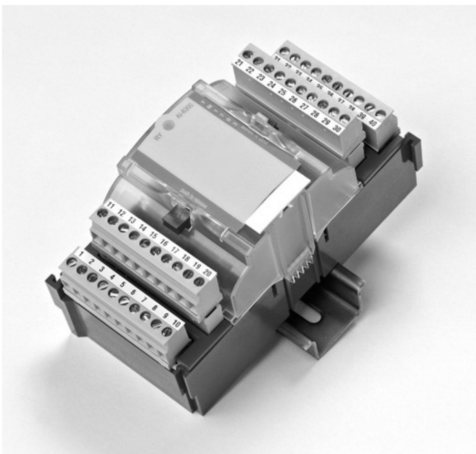
3.16. I/O Module AI-6300

3.16.1. Features and Functions

Analog input module

- 4 inputs (2 groups of 2 each)
- Galvanically insulated by optocouplers
- Acquisition of currents ±20 mA
- Acquisition of voltages ±10 V
- Removable screw terminals
- Function indication via LED
- Current Acquisition
  - Processing of analog values based on a settable cycle (0.5 to 60 s)
  - Zero-range suppression
  - Plausibility check
  - Change monitoring
  - Technological adaptation
  - Spontaneous transmission of significant changes (settable threshold)
- Voltage Acquisition
  - Processing of analog values based on a settable cycle (0.5 to 60 s)
  - Zero-range suppression
  - Plausibility check
  - Change monitoring
  - Technological adaptation
  - Spontaneous transmission of significant changes (settable threshold)

3.16.2. View



3.16.3. Technical Specifications

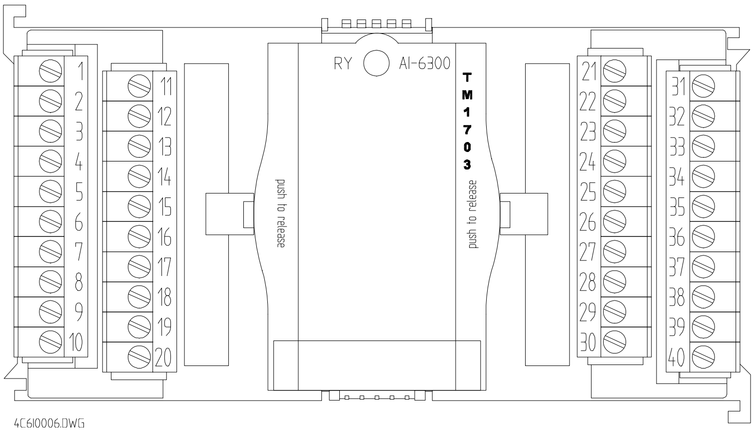
Analog Inputs	
4 analog inputs	• 2 groups, 2 inputs each • Groups are galvanically insulated from one another • Voltage between 2 inputs of a group max. 4 VDC
Measuring ranges	Current measurement -20…0…+20 mA Voltage measurement -10…0…+10 V Overrange typ. 2%
Resolution	0.013% at ±20 mA 0.025% at ±10 V
Accuracy	0.15% at 25°C 0.4% at 0…50°C 0.5% at –20…70°C
Input impedance	122.5 Ω at ±20 mA 11.3 kΩ at ±10 V
Common mode rejection ratio	
Current inputs	min. 70 dB (10 Hz…1 MHz) min. 90 dB (10 Hz…500 Hz)
Voltage inputs	min. 73 dB (10 Hz…1 MHz) min. 90 dB (10 Hz…500 Hz)
Normal mode rejection ratio	
Current inputs	0 dB (10 Hz…7.5 kHz) +20 dB/decade (7.5 kHz…1 MHz)
Voltage inputs	0 dB (10 Hz…7.5 kHz) +20 dB/decade (7.5 kHz…1 MHz)
Input circuits	External sensors, auxiliary voltage 18 VDC…78 VDC. The circuits are operated by means of an external voltage.

Power Supply	
Operating voltage	4.7…5.1 VDC, max. 480 mW The voltage is picked off at the TM bus

Mechanics and Connectors	
Terminals	Removable screw terminals (grid size 5.08)
Dimensions	131x63x73 mm (LxWxH, dimensions w/o DIN rail)
Weight	Approx. 225 g

3.16.4. Pin Assignment and Display

The process signals must be connected to four 10-pin screw terminals. The pin assignment of the peripheral connectors is described in the following table.



4C6I0006.DWG

pin	signal	pin	signal	pin	signal	pin	signal
1	AUX V0+	11	AUX V0+	21	AUX V1+	31	AUX V1+
2	IN V0 I+	12	IN V0 U+	22	IN V2 U+	32	IN V2 I+
3	IN V0 I-	13	IN V0 U-	23	IN V2 U-	33	IN V2 I-
4	AUX V0-	14	AUX V0-	24	AUX V1-	34	AUX V1-
5	AUX V0+	15	AUX V0+	25	AUX V1+	35	AUX V1+
6	IN V1 I+	16	IN V1 U+	26	IN V3 U+	36	IN V3 I+
7	IN V1 I-	17	IN V1 U-	27	IN V3 U-	37	IN V3 I-
8	AUX V0-	18	AUX V0-	28	AUX V1-	38	AUX V1-
9	AUX V0-	19	AUX V0+	29	AUX V1+	39	AUX V1-
10	AUX V0-	20	AUX V0+	30	AUX V1+	40	AUX V1-

4C6I0006.DWG

IN V0 U+/- ... IN V3 U+/- . . analog voltage inputs 0 ... 3
IN V0 I+/- ... IN V3 I+/- . . . analog current inputs 0 ... 3
AUX V0+/-, AUX V1+/- . . voltage distribution
RY . . . . Ready LED, module operational

4C6I0006.DWG

Appendix V

Specification sheets for the digital input module

DI-6100

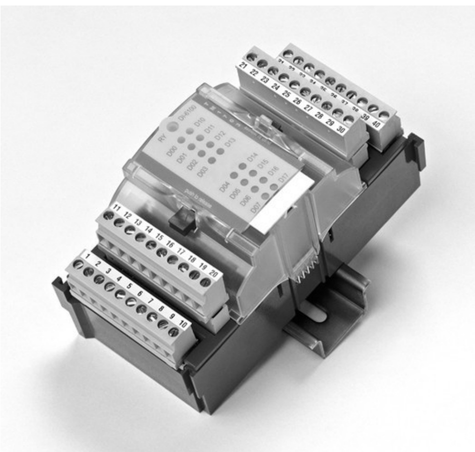
3.6. I/O Module DI-6100

3.6.1. Features and Functions

Binary input module

- 16 inputs (2 groups of 8 each)
- Galvanically insulated by optocouplers
- Each group has a common return
- Signal voltage 24-60 VDC
- Removable screw terminals
- The states of the inputs are indicated via LEDs
- Single-point information
  - Acquisition and processing in a 10 ms grid
  - Inverting
  - Spontaneous transmission of changes
- Double-point information
  - Acquisition and processing in a 10 ms grid
  - Inverting
  - Monitoring intermediate and faulty positions
  - Spontaneous transmission of changes
- Count pulses
  - Acquisition with a maximum count frequency of 20 Hz
  - Inverting
  - Counter value formation
    - Current absolute value
  - Formation of counts (integrated totals)
    - Latched absolute value
  - Transmission on request or based on a settable cycle

3.6.2. View



3.6.3. Technical Specifications

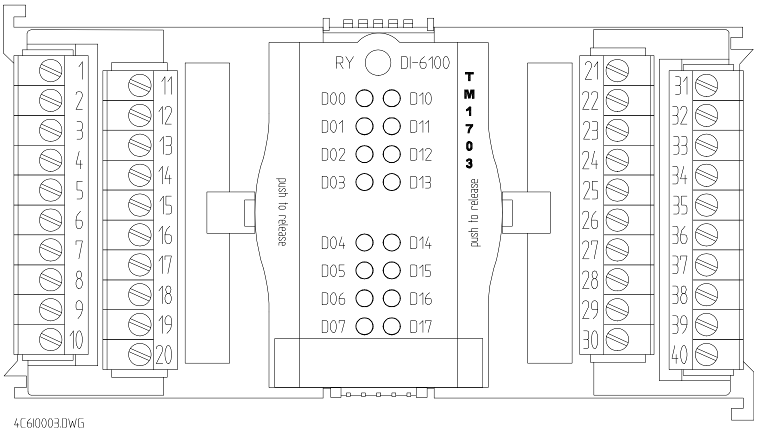
Binary Inputs	
16 binary inputs	• 2 groups, 8 inputs each • Galvanical insulation • Each group has a common return of selectable polarity
Filter time	One dedicated input 2 ms All other inputs 3 ms
Nominal voltages	24/48/60 VDC
Operating points	≤ 12 V logically "0" ≥ 16 V logically "1"
Rated current	1.0…1.5 mA (at 18…78 V)
Input circuits	18…78 VDC The circuits are operated by means of an external voltage

Power Supply	
Operating voltage	4.7…5.1 VDC, 170 mW The voltage is picked off at the TM bus

Mechanics and Connectors	
Terminals	Removable screw terminals (grid size 5.08)
Dimensions	131x63x73 mm (LxWxH, dimensions w/o DIN rail)
Weight	Approx. 225 g

3.6.4. Pin Assignment and Display

The process signals must be connected to four 10-pin screw terminals. The pin assignment of the peripheral connectors is described in the following table.



4C6I0003.DWG

pin	signal	pin	signal	pin	signal	pin	signal
1	IN D00	11	AUX V0+(-)	21	AUX V1+(-)	31	IN D10
2	IN D01	12	AUX V0+(-)	22	AUX V1+(-)	32	IN D11
3	IN D02	13	AUX V0+(-)	23	AUX V1+(-)	33	IN D12
4	IN D03	14	AUX V0+(-)	24	AUX V1+(-)	34	IN D13
5	IN D04	15	AUX V0+(-)	25	AUX V1+(-)	35	IN D14
6	IN D05	16	AUX V0+(-)	26	AUX V1+(-)	36	IN D15
7	IN D06	17	AUX V0+(-)	27	AUX V1+(-)	37	IN D16
8	IN D07	18	AUX V0+(-)	28	AUX V1+(-)	38	IN D17
9	AUX V0-(+)	19	AUX V0+(-)	29	AUX V1+(-)	39	AUX V1-(+)
10	AUX V0-(+)	20	AUX V0+(-)	30	AUX V1+(-)	40	AUX V1-(+)

4C6I0003.DWG

AUX V0+/-, AUX V1+/- . . voltage distribution
IN D00 ... IN D07 . . . . binary inputs group 0, binary inputs 0 ... 7
IN D10 ... IN D17 . . . . .binary inputs group 1, binary inputs 0 ... 7
RY . . . . Ready LED, module operational
D00 ... D07, D10 ... D17 . . . LED lights up, if the appropriate input is set

4C6I0003.DWG

Appendix VI

Specification sheets for the digital output module

DO-6200

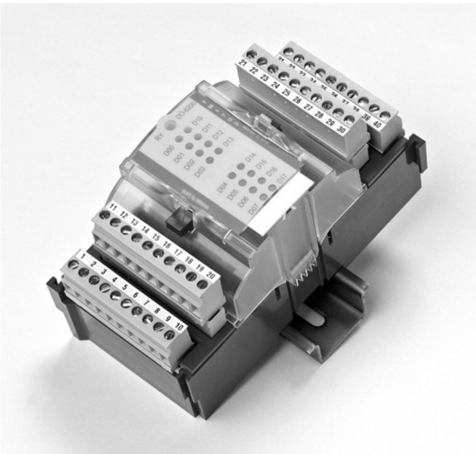
3.11. I/O Module DO-6200

3.11.1. Features and Functions

Binary output module

- 16 transistor outputs (2 groups of 8 each)
- Galvanically insulated by optocouplers
- Each group has a common return (plus)
- All outputs proof against overload and continued short circuit
- To increase switching capacity 2 outputs can be connected in parallel
- No impact on other outputs if one is short-circuit
- Removable screw terminals
- The states of the outputs are indicated via LEDs
- Pulse commands
  - Single commands
  - Double commands
- Binary information output
  - Spontaneous output of single-point information
  - Selectable behavior on failure of communication

3.11.2. View



3.11.3. Technical Specifications

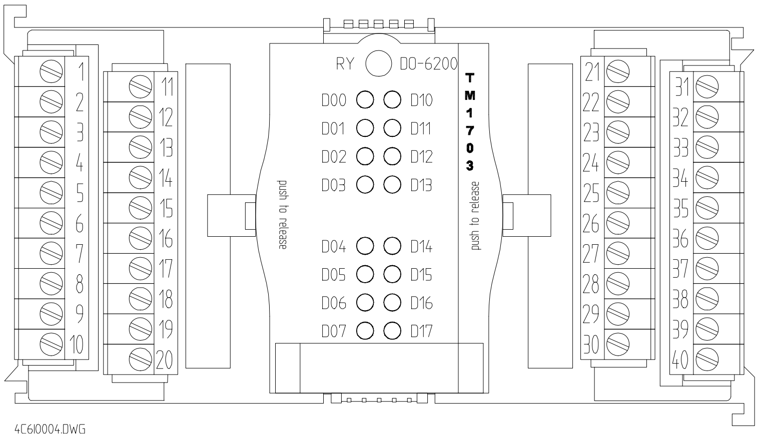
Binary Outputs	
16 binary outputs (transistor)	• 2 groups, 8 outputs each • Galvanical insulation • Each group has a common return
Nominal switching voltage	24/48/60 VDC
Nominal current (resistive load)	Due to thermal loading capacity of the module: • 0.25 A at 24, 48, and 60 VDC (for each output, if 16 outputs are active at the same time) • 0.35 A when connecting 2 outputs in parallel (for each pair ot outputs, if 8 pairs of outputs are active at the same time)
Maximum continuous current	Due to electrical ratings of the transistor switch: • 0.9 A at 18…78 VDC (only 1 output active)
Nominal switching capacity (resistive load, U_N)	• 6 W at 24 VDC when connecting in parallel: 8.4 W • 12 W at 48 VDC when connecting in parallel 16.8 W • 15 W at 60 VDC when connecting in parallel: 21 W
Maximum switching capacity	70.2 W at 78 VDC
Overload proof	No
Proof against continued short-circuit	10 A current limitation If the current limitation operates, current is cut off after 10 µs Cyclic reclosing break time 300 µs make time 10 µs
Switching cycles	Unlimited
Switching frequency	Max. 100 Hz
Output circuit voltage drop	< 0.5 V at 0.25 A
Dynamic withstand capability	• Capacitive load max. 100 nF at 60V • Inductive $\tau \leq$ 500 ms (any with external free-wheeling diode) • Lines Z ≥ 100 Ω, line length up to 3 km • Lamps $I_N \leq$ 150 mA ($I_{ON} \leq$ 1.8 A)
Output circuits	18…78 VDC The circuits are operated by means of an external voltage

Power Supply	
Operating voltage	4.7…5.1 VDC, 600 mW The voltage is picked off at the TM bus

Mechanics and Connectors	
Terminals	Removable screw terminals (grid size 5.08)
Dimensions	131x63x73 mm (LxWxH, dimensions w/o DIN rail)
Weight	Approx. 260 g

3.11.4. Pin Assignment and Display

The process signals must be connected to four 10-pin screw terminals. The pin assignment of the peripheral connectors is described in the following table.



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pin	signal	pin	signal	pin	signal	pin	signal
1	AUX V0-	11	OUT D00	21	OUT D10	31	AUX V1-
2	AUX V0-	12	OUT D01	22	OUT D11	32	AUX V1-
3	AUX V0-	13	OUT D02	23	OUT D12	33	AUX V1-
4	AUX V0-	14	OUT D03	24	OUT D13	34	AUX V1-
5	AUX V0-	15	OUT D04	25	OUT D14	35	AUX V1-
6	AUX V0-	16	OUT D05	26	OUT D15	36	AUX V1-
7	AUX V0-	17	OUT D06	27	OUT D16	37	AUX V1-
8	AUX V0-	18	OUT D07	28	OUT D17	38	AUX V1-
9	AUX V0-	19	AUX V0+	29	AUX V1+	39	AUX V1-
10	AUX V0-	20	AUX V0+	30	AUX V1+	40	AUX V1-

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AUX V0+/-, AUX V1+/- . .voltage distribution
OUT D00 ... OUT D07 . . . .binary outputs group 0, binary inputs 0 ... 7
OUT D10 ... OUT D17 . . . . binary outputs group 1, binary inputs 0 ... 7
RY . . . . Ready LED, module operational
D00 ... D07, D10 ... D17 . . LED lights up, if the appropriate output is set

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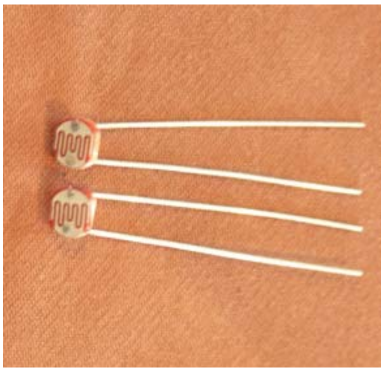
Appendix VII

Specification sheets for the light dependent resistor (LDR)

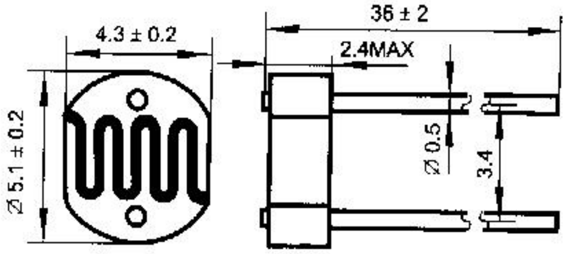
CdS PHOTOCONDUCTIVE CELLS GL5528



- ▲ Epoxy encapsulated
- ▲ Quick response
- ▲ Small size
- ▲ High sensitivity
- ▲ Reliable performance
- ▲ Good characteristic of spectrum

Light Resistance at 10Lux (at 25℃)	8～20KΩ
Dark Resistance at 0 Lux	1.0MΩ(min)
Gamma value at 100-10Lux	0.7
Power Dissipation(at 25℃)	100mW
Max Voltage (at 25℃)	150V
Spectral Response peak (at 25℃)	540nm
Ambient Temperature Range:	- 30～+70℃

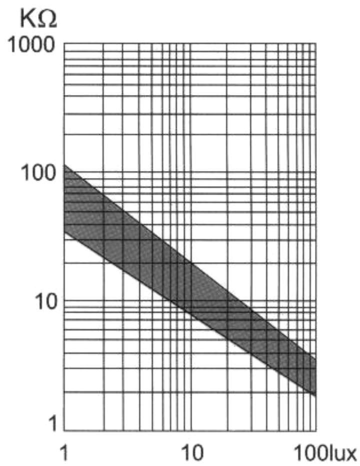
Outline



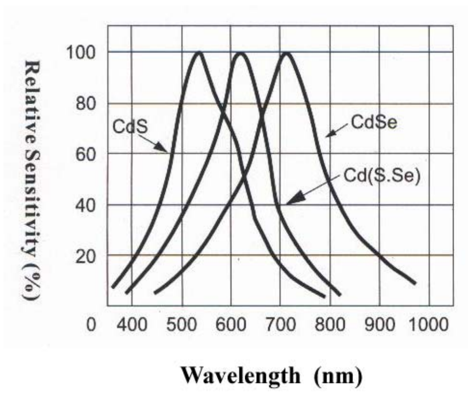
Measuring Conditions

1. Light Resistance:
   measured at 10 lux with standard light A (2854k color temperature) and 2h pre-illumination at 400-600 lux prior to testing.
2. Dark Resistance:
   measured 10 seconds after pulsed 10 lux.
3. Gamma Characteristic:
   between 10 lux and 100 lux and given by
   $$T = \frac{\log (R10/R100)}{\log (100/10)} = \log (R10/R100)$$
   R10, R100 cell resistance at 10 lux and 100 lux.
   The error of T is +0.1.
4. Pmax:
   Max. power dissipation at ambient temperature of 25°C.
5. Vmax:
   Max. voltage in darkness that may be applied to the cell continuously.

Illuminance Vs. Photo Resistance



Spectral Response



LIDA OPTICAL&ELECTRONIC CO., LTD.

254,Zhong zhou road, Nanyang, Henan,P.R.C
TEL: +86-377-6313 0034
FAX: +86-377-6315 2372
E-mail: sale@nylida.com
Http://www.nylida.com

Gmail by Google

wd salah <wd.salah09@gmail.com>

ACIIDS 2015: kind reminder about registration and fee payment for paper 101

1 message

ACIIDS 2015 <aciids2015@easychair.org> Wed, Dec 24, 2014 at 11:50 PM
To: Mohamed Salam Musa <wd.salah09@gmail.com>

Dear Professor Mohamed Salam Musa,

If you have already registered for ACIIDS 2015 and paid conference fee, please skip this email.

We would like to remind you gently that the deadline for registration and payment of the author's conference fee expires soon, on December 31, 2014

Your paper # 101 titled:
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has been accepted by ACIIDS 2015 Program Committee to be ORALLY presented at the conference and published in the Springer LNAI volume (A). Congratulations once again!

By December 31, 2014 at least one of the authors must register using the ACIIDS 2015 website and pay the author's conference fee. For registration details please visit: http://www.aciids.org/?page=Registration and Fees.YS

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Special sessions: d.barbucha@wpit.am.gdynia.pl

Thank you very much for your contribution and we look forward to meeting you in Bali.
WE WISH YOU A VERY HAPPY NEW YEAR !

With best regards,
Ngoc Thanh Nguyen
Ford Lumban Gaol
ACIIDS 2015 General Chairs
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