# Smart Mechanical Ventilation and Artificial Lighting Implementation in the Restroom for Energy Efficiency

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## Abstract

The window is one of the most important aspects of a building. It aims to obtain good lighting and meet the requirements for Indoor Air Quality. A restroom is a place where most surfaces are wet, and it causes the relative humidity to become high. As a result, lighting must be considered in this space. The men's toilet on the second floor of the Bina Nusantara University campus in Malang is the subject of this research. Interviews with building operators, cleaners and firsthand surveys of the location were also undertaken. The author used the results of interviews to help specify the ventilation system. The author utilizes a lux meter to measure the lighting layout. According to the findings, this toilet uses mechanical ventilation in the form of an exhaust fan. On the other hand, this area employs downlights that meet lighting standards in terms of brightness and color temperature selection in the artificial lighting system. In the current situation, there is a shortage of energy efficiency. As a result, this study offers a method for preserving electrical energy. This study uses an Arduino Mega and several sensors to help automate the operation of these electrical devices.

## Keywords
Arduino, Artificial Lighting, Energy-Saving, Mechanical Ventilation and Restroom.

## 1. Introduction
The restroom is a high-humidity room because it contains clean and unclean water. The toilet's indoor air quality (IAQ) is frequently contaminated by pollutants derived from human excreta (Zhang et al., 2021). Polluted air can contribute to the development of respiratory infections, asthma, and lung cancer (He et al., 2021). Mainly if the air in the toilet is foul, forcing inhabitants to avoid going to the bathroom, which results in chronic diseases and psychiatric problems (Lin, 2021). Ventilation is required to remedy the harmful air in the room. Natural ventilation is one method of overcoming poor indoor air quality, as trapped air in the toilet can escape via the window or doorway. Additionally, this natural ventilation provides energy-saving benefits (Lin, 2021).

Natural ventilation is generally created by placing a window against one wall. If natural ventilation is not possible, mechanical ventilation can be applied, such as placing an exhaust fan on the ceiling. The exhaust fan can remove hot temperatures in the room, high humidity, and odours due to ammonia. In addition to removing unhealthy air, the exhaust fan will automatically draw clean air outside.

In addition to providing natural ventilation, Windows can also give natural lighting (Yu, 2021) in the restroom. Because the toilet is wet, lighting is needed. Slipping is one of the incidents that occur in the toilet. Therefore, insufficient lighting in the toilet might threaten individuals who access it (Şahin & Erkal, 2017). Slipping has serious repercussions, as it can result in a head accident. Some post-stroke patients and the elderly are considerably more

cautious when using this restroom. Falling is a frequent occurrence following stroke, occurring during the acute, rehabilitative, and chronic periods. Falls can result in death or severe damage, minor injuries, functional limits, hip fractures, decreased mobility and activity, and fear of falling, which is a significant psychological consequence of falls (Abd-Almageed et al., 2020). They are folks who are highly vulnerable if they fall into it. Artificial lighting can be utilised to place light spots in the toilet if natural illumination is not possible (Kurnia et al., 2014).

Artificial lighting and ventilation in restrooms should not be left 24 hours a day. Compared to other rooms in a structure, this section is rarely used. Several studies on energy savings have been undertaken, such as the use of Passive Infrared (PIR) sensors to turn off and on lights (Ensor, 2015; Perkasa et al., 2021). This sensor has a limitation in its application in that it only detects movement within the covered region (Saha et al., 2022). If this sensor does not detect any movement during a specific period, it will switch off the light. In its closet application, someone conducting bowel motions likely to make a slight movement. When a PIR sensor is used alone, the chance of misreading is exceptionally high; therefore, adding another sensor to assist the PIR sensor in its operation is essential. The ultrasonic sensor is a sensor that may be used with a PIR sensor to determine whether or not there are people in the surrounding area.

## 2. Literature Review

### 2.1 Mechanical Ventilation Determination

Every room must have an opening in the form of a window or roster hole to get a standard in AIQ. Its goal is to improve the airflow in the room. Each room has a particular air change standard, according to the German Institute for Standardization, Deutsches Institut für Normung (DIN) 1946 part 2 (Deutsches Institut für Normung, 1999). Bedrooms get 2-4 air changes per hour (ACH), kitchens get 10-15, and bathrooms get 6-10. If a room lacks natural ventilation, mechanical ventilation in an exhaust fan should be provided. The size of the exhaust fan is determined by multiplying the volume of the room by ACH. The calculation of air volume is the Cubic Meter Hour (CMH). As a result, it is possible to formulate the formula CMH = volume of space x ACH.

According to Building Regulations Part M (HM Government, 2020), the standard toilet cubicle size is 85cm x 150cm. The CMH requirement can be estimated by taking the average ceiling height of 280cm and multiplying it by 0.85m X 1.5m X 2.8m x 10. This multiplication results in an air volume of 35.7 CMH. KDK 10EGSA is an example of a product that can be used. It is the most smallish type and has an air volume of 75 CMH (KDK Indonesia, 2020). This kind of exhaust fan is mounted on the ceiling and can be used for two identical-sized toilets. It can be placed in the center of the toilet cubicle for location. This exhaust fan requires 5.5 watts of power to operate.

In addition to estimating the air volume in the toilet, the relative humidity must also be considered (RH). It is the ratio of the vapor pressure of air to the saturation vapor pressure (Kong & Singh, 2016). The higher the RH, the wetter the location. In general, the RH in a room ranges from 45 to 65%, while the RH in public restrooms is 40 to 50% (Kementerian Kebudayaan dan Pariwisata, 2019). Because the toilet is constantly in contact with water, this region is prone to high humidity. The toilet RH can be kept at an average level by utilizing an exhaust fan.

### 2.2 Lighting for Toilet Purpose

This room requires enough lighting to prevent bathroom accidents. If the natural lighting is not possible in this space, it is necessary to provide artificial lighting in the form of lamp installations. The illuminance standard for toilets is 100-200 lux. The lux is an illuminance measurement unit derived from the International System of Units (SI), which measures light flux per unit area equal to one lumen per square meter. It can be written the formula that LUX=lumens/m2 (Owhor & Uchenna, 2021).

The correlated color temperature (CCT) is used to determine the standard illuminance for toilets, and the unit measurement is Kelvin (K). In artificial lighting, CCT ranges range from 2700K to 6500K. The color will be more yellow when the CCT number is close to 2700K. When the CCT number approaches 6500K, the color tends to be white. Toilets have a CCT range of 2700-3000K.

### 2.3 PIR Sensor and Ultrasonic Sensor In Arduino Mega Board

The Arduino Mega is an open-source microcontroller board that uses the Microchip At mega 2560 microprocessor (Arduino, 2021). The board has 14 digital and six analogue I/O pins that can be used to link to a variety of expansion

boards and circuits. Arduino IDE (Integrated Development Environment) is software to program the Arduino Mega board (Aryani et al., 2019). Table 1 shows the product's entire specifications.

Table 1. Technical specs

| Microcontroller | ATmega2560 |
|---|---|
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limit) | 6-20V |
| Digital I/O Pins | 54 (of which 15 provide PWM output) |
| PWM Digital I/O Pins | 15 |
| Analogue Input Pins | 6 |
| DC Current per I/O Pin | 20 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 256 KB of which 8 KB used by bootloader |
| SRAM | 8 KB |
| EEPROM | 4 KB |
| Clock Speed | 16 MHz |

Arduino Mega supports many sensors, and some of them are the ultrasonic sensor HC-SR04, PIR sensor HC-SR501, and DHT22 as relative humidity and temperature sensor. A sensor that translates physical quantities (sound) into electrical quantities and vice versa is known as an ultrasonic sensor. It is based on sound wave reflection and can be used to determine an object's existence (distance) with a specific frequency (Adebola Olayinka et al., 2021; Lee & Chang, 2014). Because it uses ultrasonic waves (ultrasonic sound) at a frequency of 20,000 hertz, it is called an ultrasonic sensor. This form of ultrasonic sound is inaudible to human hearing (Susilo et al., 2021).

At the same time, the PIR sensor is a device that detects changes in the infrared radiation emitted by moving warm-blooded objects within its detection range (Akinwumi et al., 2021; Perkasa et al., 2021). This sensor detects human movement in the proximity of this circuit (Tiwari et al., 2016). This sensor is an input system and commands the output if there is a condition change. If there are people near the sensor, for example, the system will automatically command the output to turn on the light (Ensor, 2015), alarm (Thu et al., 2020), or a fan (Kanchanasatian, 2018).

The third sensor used is to measure the temperature and humidity of the room, namely the DHT22 sensor. This sensor was chosen over the DHT11 sensor because it delivers higher temperature and humidity accuracy. DHT22 measures temperature and humidity more accurately by 4% and 18%, respectively (Adhiwibowo et al., 2020). This sensor will read the ambient room temperature as an input to the Arduino system. If the sensor senses the required lower or higher amount, outputs such as exhaust fans will be activated (Dahlan et al., 2018).

## 3. Methods

In this study, the author will focus on optimizing electrical energy in the toilet. A lux meter was used in this investigation to evaluate the luminance in the room. The author also conducts a case study at the men's restroom on the second floor of Bina Nusantara University's Malang campus. The author conducted conversations with building managers and did site surveys. The author inquired about the sort of exhaust fan used in the toilet with the building manager to learn more about the exact hardware parameters, particularly the air volume of the toilet devices. This lavatory is now surrounded by numerous rooms, making it impossible to install windows for natural ventilation and light. As a result, this space has been equipped with mechanical ventilation and artificial lighting. This toilet is equipped with an energy-saving PIR sensor connected to the lamp. The light will switch on automatically for 90 seconds when the PIR detects motion. Mechanical ventilation works continuously for 24 hours.

To optimize the electrical energy in this toilet, the author did additional in-depth research. An Arduino Mega device is equipped with a PIR sensor, temperature and humidity sensor, and ultrasonic sensors used as inputs. PIR sensor and Ultrasonic HC-SR04 sensor act as input to control the lamp as output. On the other hand, the DHT22 temperature and humidity sensor acts as an input. The system works to optimize energy in the toilet equipped with Arduino Mega, the PIR sensor, DHT22 temperature and humidity sensor, and Ultrasonic HC-SR04 sensor, as seen in the following flowchart image. Figure 1 show the flowchart of lighting and exhaust fan control.
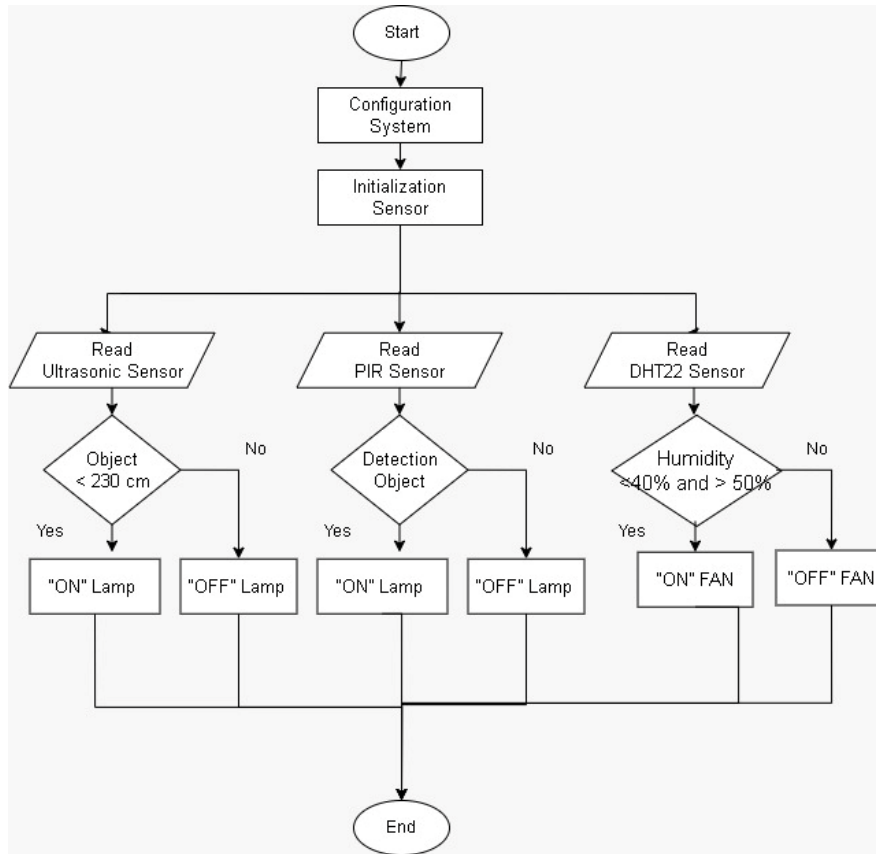


Figure 1. Flowchart of lighting and exhaust fan control

## 4. Results and Discussion

### 4.1 Existing Layout and Electrical Installation

The front of the toilet is currently a sink with three sink bowls. There are four toilet cubicles next to the sink. Three urinals are located just across from the toilet cubical. There are two lamps in the sink area, one in the urinal area, and one in each cubicle in this toilet. There is also an exhaust fan in the sink area, two in the urinal area, and three exhaust fans on the cubicle space's perimeter. Figure 2 depicts the electrical installation specifics of the plan.
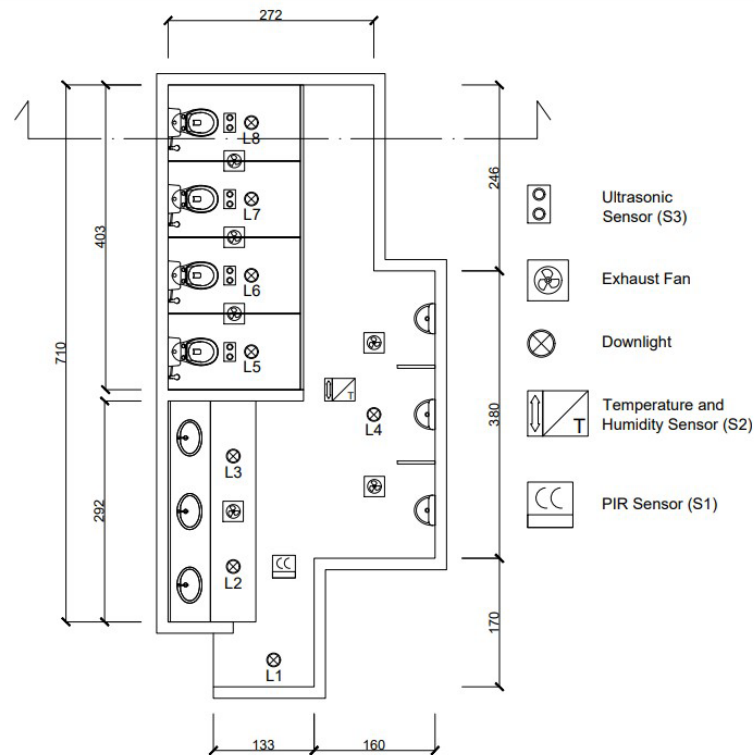
Figure 2. Layout and electrical installation

The author used a lux meter to take measurements on this toilet, and the results show that the illumination in the room meets the standard of 120-150 lx. The light color version fulfils the 3000K requirement as well. L1 is at the restroom's entrance and is always on. The PIR sensor controls L2, L3, and L4, which are connected in series. At the same time, L5-L8 is active 24 hours a day. L2-L8 is initially connected to the PIR sensor in the early planning. Only L2-L4 is linked to the PIR sensor as needed, while L5-L8 is left on for 24 hours.

The PIR sensor is mounted on the ceiling next to the sink, in front of the toilet. L2-L4 will light up for 90 seconds when someone enters the toilet. This amount of time is regarded as adequate for washing hands or using the urinal. However, activities in the toilet take longer than other activities, such as hand washing and urinating. Because the PIR sensor cannot identify someone entering the cubicle, this instrument detects no movement. L2-L4 will automatically turn off by itself if it reaches 90 seconds. When someone uses the restroom, the light will turn back on. Hand washing operations that last longer than 90 seconds are also not detected by the PIR sensor, implying that this PIR sensor has a reading problem. At the same time, the toilet exhaust fan is running nonstop for 24 hours.

## 4.2 Automation in Lighting System
The author will use engineering to automate toilet lights in this study. The lights in the toilets are divided into two sections: the primary lighting, which uses general lighting, are connected to the PIR sensor, and the secondary light, which utilizes accent lighting. The main lighting consists of L2-L4. The next light is secondary lighting on each toilet controlled by an ultrasonic sensor, and they are L4-L8. Because there are four cubicles inside the toilet, four-light points must be installed above the toilet. Each ultrasonic sensor is attached to a bulb. The PIR sensor detects movement when someone enters the toilet and only turns on the primary lighting for 2 minutes. Hand cleaning and urinating should take no more than 2 minutes. As a result, after peeing, toilet users will rush to the sink to wash their hands. The primary lighting stays on because of activity in the sink signals to the PIR sensor.

When someone uses the toilet for the first time, the PIR sensor will trigger the primary lighting to switch on for three minutes. It takes more than 5 minutes on average for people to complete activities in the toilet. Because the PIR sensor does not detect humans entering the cubicle room, the lights will switch off automatically after 3 minutes. The ultrasonic sensor detects a change in the distance when the user is above the toilet. The sensor will measure the ceiling

height of the toilet seat by 230cm in the starting conditions. Subtract 270 cm from the ceiling height and 40 cm from the toilet seat height to get this amount. There will be a change in the number indicating less than 230cm if someone is on the toilet seat. This sensor then turns on the light above the cubicle. Figure 3 shows comprehensive information on the cubicle's size.
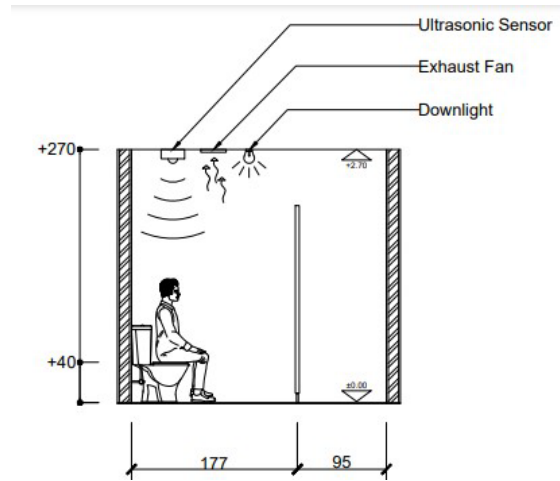


Figure 3. An intersection in the closet room

After about 5 minutes or more, the user leaves the toilet, and the distance between them shifts. When the sensor detects a distance of 230cm as an initial digit, it activates the primary lights for 3 minutes. Its purpose is to make the individual's walk to the sink more pleasant. The user sends a signal to the PIR sensor to switch on the primary illumination for 3 minutes when they reach the sink area. The scenario of a person entering cubicle 1 appears to be like truth Table 2.

Table 2. Truth table for lighting

| Name | L1 | L2-L4 | L5 | L6 | L7 | L8 |
|---|---|---|---|---|---|---|
| No body in the toilet | On | Off | Off | Off | Off | Off |
| User enters to toilet | On | On | Off | Off | Off | Off |
| User enter to cubical 1 | On | On | On | Off | Off | Off |
| After 3 minutes | On | Off | On | Off | Off | Off |
| User leaves cubical 1 | On | On | Off | Off | Off | Off |
| User goes to wash basin | On | On | Off | Off | Off | Off |
| User leaves toilet, wait for 3 minutes | On | Off | Off | Off | Off | Off |

### 4.3 Automation in Mechanical Ventilation

The toilet exhaust fan is divided into the primary and closet sections. There are two exhaust fans mounted above the sink and above the urinal in the main section. There are three exhaust fans situated between the cubicle baffles in the toilet part. Because the main section's room volume is 28 m3, a 280 CMH exhaust fan is required. It is calculated by multiplying the room volume by 10 ACH, which is the DINS 1946 part 2 standard. If the room has three exhaust fans, the 280 CMH is divided by three. The final result is 93 CMH. At the same time, the volume of the two cubicle rooms in the closet part is 1.77m x 1m x 2.7m x 2 rooms. Multiplication produces a value of 9.6 m3. Therefore, multiplying 10 ACH by two results in the requirement for an exhaust fan with a minimum capacity of 93 CMH for the two cubicles. This instrument should be placed in the middle of the two cubicles to get the best performance in mechanical ventilation.

Installing a temperature and humidity sensor in the middle of the toilet is required to determine whether the toilet is within the 40-50% humidity range, which is the standard for toilet humidity. If the RH of the toilet is greater than 50%

or less than 40%, the sensor will turn on all exhaust fans. When the sensor detects a 45% RH, an average of 40-50%, the device will turn off automatically. It chooses 45% as the stopping point because it wants to avoid having to turn on and off the exhaust fan during the RH change. Setting the value of 50% as the stopping point if the RH is high, for example, will result in the exhaust fan turning on again after a few minutes when the number indicates an RH of 51%. Because the exhaust fan frequently switches on and off, this number range damages the exhaust fan's continuity.

Apart from being controlled by the temperature and humidity sensor, the exhaust fan positioned in the closet area will also be controlled by an ultrasonic sensor. Even if the room RH is in the 40-50% range, the ultrasonic sensor will switch on immediately if it detects a person. Fan 1 will be controlled by ultrasonic sensors 1 and 2, while fan two will be controlled by sensors 3 and 4. Table 3 depicts the scenario for operating the exhaust fan.

Table 3. Truth table for exhaust fan

| Name | F1-F3 | F4 | F5 | F6 |
|---|---|---|---|---|
| No body in the toilet, RH 40-50% | Off | Off | Off | Off |
| No body in the toilet, RH >50% | On | On | On | On |
| No body in the toilet, RH <40% | On | On | On | On |
| User in the cubicle 1, RH 40-50% | Off | On | Off | Off |
| User in the cubicle 2, RH 40-50% | Off | Off | On | Off |
| User in the cubicle 3, RH 40-50% | Off | Off | On | Off |
| User in the cubicle 4, RH 40-50% | Off | Off | Off | On |

## 4.4 Input Output Installation

Five sensors are required as inputs for the automation of bathroom lights and exhaust fans. The first sensor is a three-pin PIR sensor called the HC-SR501. The PIR sensor's VCC, Out, and Ground pins are linked in order to the Arduino board's +5V, 2, and ground pins. The second sensor is the DHT22 temperature and humidity sensor, with three pins. The VCC, Data, and ground pins on the DHT22 sensor are linked to the Arduino board's +5V, 3, and ground pins.

The ultrasonic sensors, which have four pins, are the third through sixth sensors. A 5V Arduino board is used to link the three VCC ultrasonic sensors. At the same time, ground pins connect to the Arduino board system's ground. The ultrasonic sensor's first trigger pin is connected to pin four on the Arduino board, while the first echo pin is connected to pin 5. The ultrasonic sensors for the second trigger and echo pins are connected to pins 6 and 7, while the third trigger and echo pins are connected to pins 8 and 9 on the Arduino board. The ultrasonic sensor's fourth trigger pin is connected to pin ten on the Arduino board, while the fourth echo pin is connected to pin 11.

The system uses an eight-channel relay for output. Pins 12-19 of the Arduino board are sequentially connected to ins 1-8. The Arduino board's +5V pin is connected to the VCC pin on the relay. At the same time, the ground pin on the relay is connected to the ground on the Arduino board. The relay is linked to the lamp and exhaust fan in the order shown in Table 4 for NO and COM K1 through K7.

Table 4. Eight channel relay connection to Arduino Mega

| 8 Channel 5V Relay Module | Arduino Mega Atmega2560 |
|---|---|
| NO & COM K1 | Main lighting |
| NO & COM K2 | Lighting Cubicle 1 |
| NO & COM K3 | Lighting Cubicle 2 |
| NO & COM K4 | Lighting Cubicle 3 |
| NO & COM K5 | Exhaust Fan Main section (F1-F3) |
| NO & COM K6 | Exhaust Fan Cubicle 1-2 (F4) |
| NO & COM K7 | Exhaust Fan Cubicle 2-3 (F5) |
| NO & COM K8 | Exhaust Fan Cubicle 3-4 (F6) |

The detail of the input and output installation of the component is represented in Figure 4.
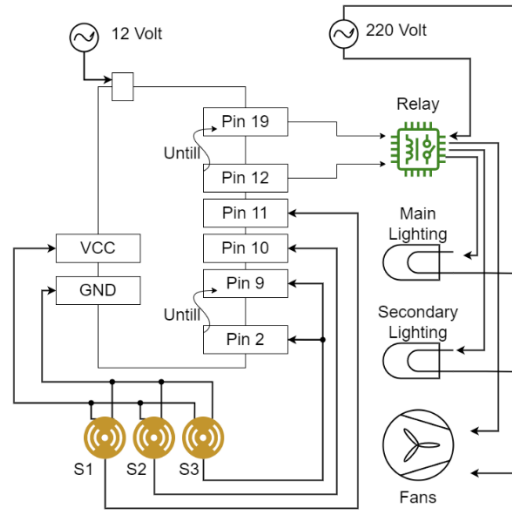


Figure 4. Schematic diagram

It is currently a prototype study, and the results have not been compared before and after the device was installed. However, in terms of concept and operation, this instrument can provide energy efficiency by optimizing lighting and exhaust fans. According to Table 2 above, the lights only turn on when there are people present and when the needs of the space are met. While the exhaust fan does not run continuously, it operates following the sensor reading conditions, as shown in Table 3 above.

## 5. Conclusion

On the 2nd floor of the Bina Nusantara Malang campus, the lighting system for men's bathrooms has been installed according to standards. It may be seen from the lux meter measurement, which gives a value of 120-150 lux. This amount is based on the average value of 100-200 lux for public restrooms. Because natural ventilation is not available, this room has adopted mechanical ventilation by installing an exhaust fan type inline direct fan with a size of 450 CMH in the ventilation system. This instrument can assist with the development of good IAQ in the toilet for the long-term health of its users.

By placing a PIR sensor at the entrance, this room has automated the lighting for energy savings. Even though there are still faults in the task, the presence of this technology is quite helpful. As a result, an ultrasonic sensor must be added to aid the PIR sensor's performance in controlling the lights, particularly in the cubicle area's automation. This sensor is used to determine how far an object is nearby. This sensor reading uses the toilet seat as a reference. The sensor will detect a change in the distance if something is blocking it. This amount is used to assume that sensors in the cubicle detect humans. As long as there are objects in the closet, this sensor is responsible for turning on the lights.

The DHT22 temperature and humidity sensors aid in the automation of the exhaust fan, which operates continuously. If this sensor detects a number less than or greater than the standard, the exhaust fan is activated. The exhaust fan will only work if the humidity in the room is less than 40% or more than 50%, based on the average RH of the toilet, which is 40-50%. If the sensor detects a 40-50% humidity level, the machine will shut down immediately. As a result, the addition of these sensors can assist save electricity in the toilet by adjusting electronic equipment to the needs of the area.

This research can be applied to buildings that utilize artificial lighting and ventilation in presenting table data for energy efficiency in future research. The following researcher can compare before and after this device is installed. It will indicate the percentage of efficiency savings.

# References

Abd-Almageed, E. S., Abd-Almageed, A. S., Almasry, M. A., Fahmy, H. M., & Shehata, G. A. Effect of an educational rehabilitation program on prevention of falls after stroke. *Journal of Nursing Education and Practice*, *10*(11), 31. (2020). https://doi.org/10.5430/jnep.v10n11p31

Adebola Olayinka, A., Adewale Oluwadamilare, A., & Femi Emmanuel, A. Distance Measurement and energy conservation using Arduino Nano and Ultrasonic Sensor. *American Journal of Electrical and Computer Engineering*, *5*(2), 40. (2021). https://doi.org/10.11648/j.ajece.20210502.11

Adhiwibowo, W., Daru, A. F., & Hirzan, A. M. Temperature and humidity monitoring using DHT22 Sensor and Cayenne API. *Jurnal Transformatika*, *17*(2), 209. (2020). https://doi.org/10.26623/transformatika.v17i2.1820

Akinwumi, S. A., Ezenwosu, A. C., Omotosho, T. V, Adewoyin, O. O., Adagunodo, T. A., & Oyeyemi, K. D. Arduino based security system using Passive Infrared (PIR) motion sensor. *IOP Conference Series: Earth and Environmental Science*, *655*(1), 012039. (2021). https://doi.org/10.1088/1755-1315/655/1/012039

Arduino. *Arduino Mega overview*. (2021). Retrieved from http://store.arduino.cc/products/arduino-mega-2560-rev3

Aryani, D., Dewanto, I. J., & Alfiantoro, A. Prototype alat pengantar makanan berbasis Arduino Mega. *Petir*, *12*(2), 242–250. (2019). https://doi.org/10.33322/petir.v12i2.540

Dahlan, N., Idham Halid, A., Juhana Hashim, T., & Sakimin, S. Temperature Based control of ventilation system for optimum climate in tomato greenhouse. *Indonesian Journal of Electrical Engineering and Computer Science*, *12*(2), 655. (2018). https://doi.org/10.11591/ijeecs.v12.i2.pp655-661

Deutsches Institut für Normung. *DIN standards committee building and civil engineering*. (1999). Retrieved from https://www.din.de/en/getting-involved/standards-committees/nabau/publications/wdc-beuth:din21:14149512

Ensor, M. O. S. Automatic lighting and security system design using PIR motion sensor. *Journal Institute of Information Technology*, *14*(8), 4–8. (2015).

He, X., Zhou, G., Ma, Y., Li, L., Fu, S., Liu, S., Liu, C., He, Y., Su, Z., Liu, J., Niu, J., Zhu, W., Zhang, K., and Luo, B. Winter vacation, indoor air pollution and respiratory health among rural college students: A case study in Gansu Province, China. *Building and Environment*, *188*, 107481. (2021). https://doi.org/10.1016/j.buildenv.2020.107481

HM Government. *Access to and use of buildings: Approved document M*. (2020). Retrieved from https://www.gov.uk/government/publications/access-to-and-use-of-buildings-approved-document-m

Kanchanasatian, K. Automatic speed control and turning on/off for smart fan by temperature and ultrasonic sensor. *IOP Conference Series: Materials Science and Engineering*, *325*, 012022. (2018). https://doi.org/10.1088/1757-899X/325/1/012022

KDK Indonesia. (*Ceiling mount*. 2020). Retrieved from https://kdk.co.id/product/volume/

Kementerian Kebudayaan dan Pariwisata. *Standar toilet umum Indonesia*. (2019). Retrieved from https://pustaka.pu.go.id/informasi/resensi-buku/standar-toilet-umum-indonesia/1G82G

Kong, F., & Singh, R. P. (2016). Chemical deterioration and physical instability of foods and beverages. In *The Stability and Shelf Life of Food* (pp. 43–76). Elsevier. https://doi.org/10.1016/B978-0-08-100435-7.00002-2

Kurnia, R. D., Sari, A. D., & Suryoputro, M. R. *Proposed bathroom design for elderly using participatory ergonomics approach*. (2014).

Lee, Y., & Chang, S. Development of a verification method on ultrasonic-based perpendicular parking assist system. In *The 18th IEEE International Symposium on Consumer Electronics (ISCE 2014)* (pp. 1–3). (2014). https://doi.org/10.1109/ISCE.2014.6884292

Lin, Y. P. Natural ventilation of toilet units in K–12 school restrooms using CFD. *Energies*, *14*(16), 4792. (2021). https://doi.org/10.3390/en14164792

Owhor, S. J., & Uchenna, P. Investigating the use of efficient lighting strategy in. *9*(3), 896–911. (2021).

Perkasa, R., Wahyuni, R., Melyanti, R., Herianto, H., & Irawan, Y. Light control using human body temperature based on Arduino Uno and PIR (Passive Infrared Receiver) sensor. *Journal of Robotics and Control (JRC)*, *2*(4). (2021). https://doi.org/10.18196/jrc.2497

Saha, H. N., Roy, R., Chakraborty, M., & Sarkar, C. (2022). A crop-monitoring system using wireless sensor networking. In AI, Edge and IoT-based Smart Agriculture (pp. 345–359). Elsevier. https://doi.org/10.1016/B978-0-12-823694-9.00003-7

Şahin, H., & Erkal, S. Evaluation of the elderly' falls efficacy by their status of having a home accident and daily life activities. *Journal of Human Sciences*, *14*(3), 2308. (2017). https://doi.org/10.14687/jhs.v14i3.4451

Susilo, J., Febriani, A., Rahmalisa, U., & Irawan, Y. Car parking distance controller using ultrasonic sensors based on Arduino Uno. *Journal of Robotics and Control (JRC)*, *2*(5). https://doi.org/10.18196/jrc.25106

Thu, M. M., Swe, S. S., & Zaw, T. T. (2020). Security system with PIR sensor. *4*(6), 77–82.

Tiwari, A. K., Raj, P., Kumar, J., & Tiwary, M. A. Motion detection using PIR sensor. *International Journal of Scientific Development and Research*, *1*(5), 103–106. (2016).

Yu, Q. Design analysis of natural lighting and ventilation of underground garage with the computer-aided technology. *Journal of Physics: Conference Series*, *1744*(2), 022068. (2021). https://doi.org/10.1088/1742-6596/1744/2/022068

Zhang, Z., Zeng, L., Shi, H., Liu, H., Yin, W., Shen, H., Yang, L., Gao, J., Wang, L., Zhang, Y., & Zhou, X. CFD study on the ventilation effectiveness in a public toilet under three ventilation methods. *Energies*, *14*(24), 8379. (2021). https://doi.org/10.3390/en14248379

## Biographies

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