CHAPTER II

LITERATURE REVIEW

2.1. Light Switches

A light switch is a device that is used to turn on/off a light fixture by connecting or disconnecting the electrical current. Some light switch can also control ceiling fan or similar electrical devices and incorporate special features, like motion detector (The Home Depot, 2013).

There are four major types of light switch. These types of switch can have significant differences in their function (Formisano, n.d).

Single-Pole Switch: A simple on-off switch. Single-Pole switch is a general purpose switch that can turn on/off a light or a receptacle from a single location. It has an **on** and **off** marking (see Figure 2-1) which will not be found on a three or four way switch (Formisano, n.d.). Single-Pole Switch is also known as Single-Pole Single-Throw (SPST) Switch, since it controls one wire which is called a pole and it makes one connection which is called a throw (1728 Software Systems, 2014).

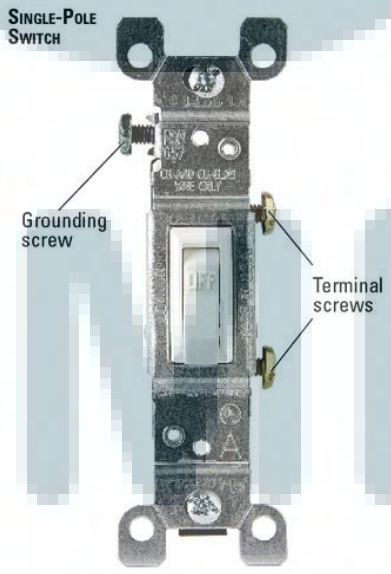

Figure 2-1 Single-Pole Switch (Source: DIYadvice, 2009)

Double-Pole Switch: By having **on** and **off** markings and similar functions to turn on/off electrical devices from one location, this type of switch is almost the same like Single-Pole Switch (Formisano, n.d.). It is also known as Double-Pole Single-Throw (DPST) or double Single-Pole Switch since it controls two wires with one connection (see Figure 2-2). Double-Pole Switch is usually used in rooms that have two entrances, or even at the top and bottom of a set of stairs, or on each end of a hall.

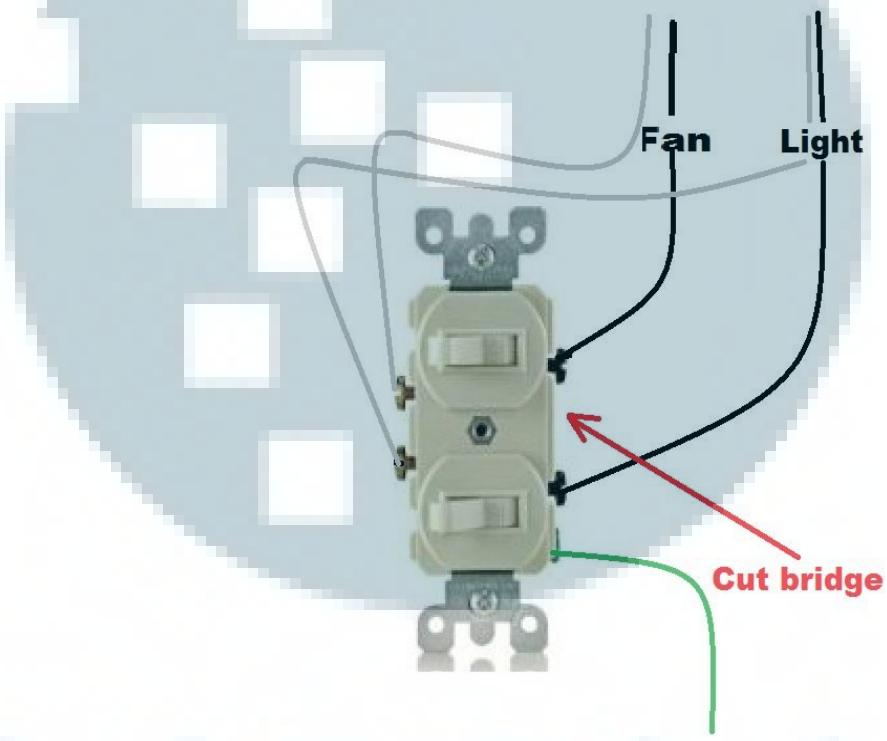

Figure 2-2 Double-Pole Switch can be called as "double" Single-Pole Switch (Source: Just Answer Electrical, 2012)

3-Way Switch: This kind of switch is always used in pairs since it can be used to turn on/off the electrical devices from two different areas (see Figure 2-3). There is no on and off markings on it because on/off state is varied when the switch is used (Formisano, n.d.). This style of switch is usually used in stairways, hallways, or large rooms.

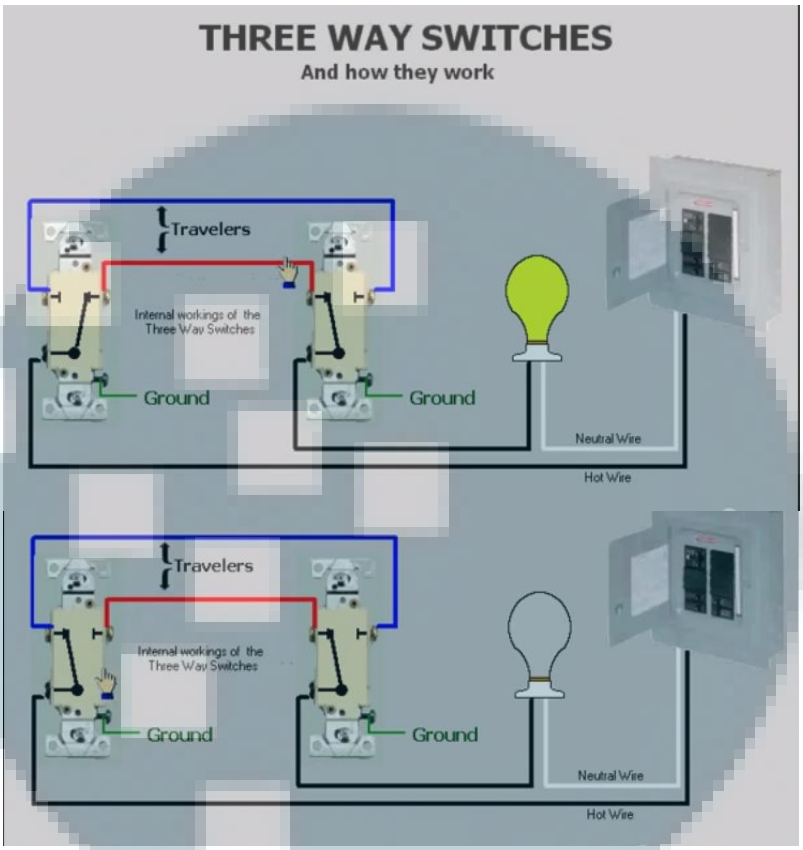

Figure 2-3 3-Way Switch (Source: Youtube, 2009)

4-Way Switch: The 4-Way Switches should be used in between two 3-Way Switches in order to be able to control the light from three locations (see Figure 2-4).

There are several styles of light switch available in the market. The style will not affect the functions (Formisano, n.d.). However, the appearances and features added by the manufactures could be different to make customers' life easier, more efficient, and more flexible.

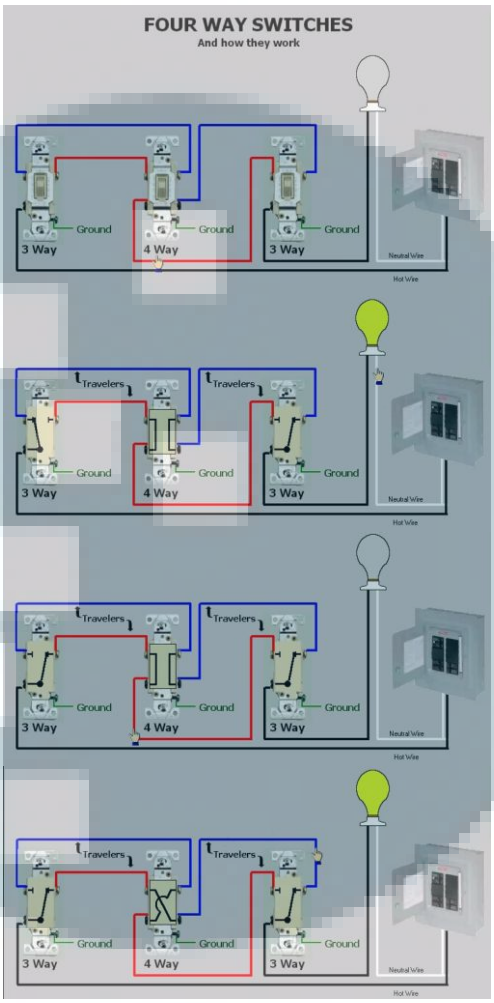

Figure 2-4 4-Way Switch (Source: Youtube, 2009)

Knife Switch: This type of switch is rarely seen nowadays. Nowadays, Knife Switch (see Figure 2-5) is only used for heavy-duty industrial or science project applications. The Knife Switch is rarely or almost never seen in household wiring nowadays since the electrical connections are exposed (1728 Software Systems, 2014).

Toggle Switch: Toggle Switch (see Figure 2-6) is one of the most common light switches. Toggle switches are actuated by a lever angled in one of two or more positions (Kuphaldt, 2007).

Figure 2-5 Knife Switch (Source: xUmp, n.d. and AllSaleh Trading Company, n.d.)

Since the contact is enclosed in the toggle switch, toggle switch is safer than knife switch especially for high voltage circuit. Toggle switch could protect the person who operates the switch for making contact to the electricity accidentally.

Figure 2-6 Toggle Switch (Source: Tandy Online, 2013)

Rocker Switch: Rocker Switch in Figure 2-7 is another the most common light switches used. This kind of switch is similar to a Toggle Switch, but operates through a rocking action on a flat lever board. When one side of the rocker switch is pressed, the other side rises and there is always a 0 mark on the "turn off" side while there is a 1 mark on the "turn on" side.

Figure 2-7 Rocker Switch (Source: Design News, 2011)

Push-Button Switch: Same like Knife Switch, Push-Button Switch, as shown in Figure 2-8, is rarely seen nowadays especially for a light switch. Push-Button Switch was first installed in the early 1890s, and was the most commonly installed switches through the 1920s but then Toggle Switch replaced the Push-Button Switch especially after 1950s (Lewis, n.d.). However, some people still use Push-Button Switch as a light switch because of its classic value. Nowadays, Push-Button Switch is the most common of actuation method and used for audio/video equipment, industrial and domestic applications, etc. (Rapid Electronics, 2014).

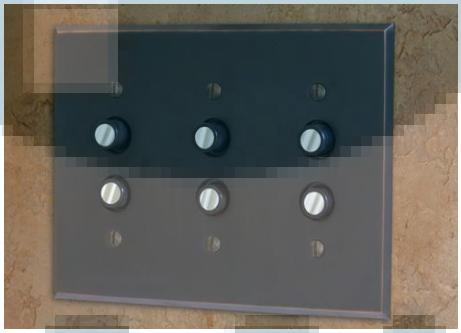

Figure 2-8 Push-Button Switch (Source: Classic Accents Inc., n.d.)

Touch Screen Switch: Touch Screen Switch (see Figure 2-9) becomes popular nowadays. While the common light switch only has on or off options and its conventional appearance, Touch Screen Switch developed by manufacturers nowadays come in a variety of colors and formats, can easily create a lighting effect in an area by using Scenes Mode (e.g. Evening Scene) to control several lights and electrical devices throughout the home, and also allow customers to dim the lights.

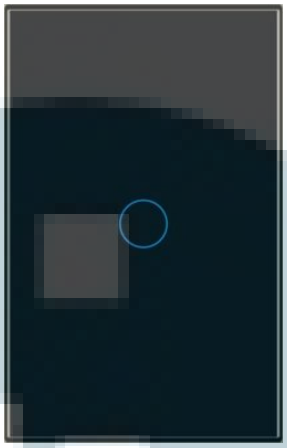

Figure 2-9 Touch Screen Switch (Source: Ali Express, n.d.)

Rotary Dimmer Switch: Same like Touch Screen Switch, Rotary Dimmer Switch (see Figure 2-10) is one of common light switches' modification from manufacturers. A rotary knob on the switch can be used to adjust the amount of the brightness either off position when it is turned to the far left, a very dim, moon-glow level, or to the full brightness when it is turned to the far right (Thiele, 2014).

Figure 2-10 Rotary Dimmer Switch (Source: eBay, n.d.)

Motion Switch: Motion Switch (see Figure 2-11) which turns on with motions is great for entryways. It utilizes Occupancy Sensor which is usually referred as Motion

Sensor or Motion Light Sensor by using passive infrared, ultrasonic or a combined multi-sensing technology as its motion detector to provide automatic ON/OFF switching of lighting loads for enhances convenience, security and long-term energy savings (Leviton Manufacturing Co., Inc., 2014a).

Figure 2-11 Motion Switch (Source: The Home Depot, 2013)

Outdoor Switch: Outdoor Switch in Figure 2-12 has a weatherproof box cover that will protect the wiring inside from harmful elements to allow it to be placed outside safely (Lightbulbs, 2014).

Figure 2-12 Outdoor Switch (Source: Sockets & Switches, 2014)

Delayed Action Switch: This kind of switch is good applied on garages, workshops, or other place where the customers might need a minute or so to get out from the room after turning off the switch since the switch will keep the circuit open for a few seconds or minutes after the switch cut off (Lightbulbs, 2014).

Illuminated Switch: Illuminated Switch shown in Figure 2-13 which is is great for children's rooms, hallways, or stairwells, has a small light that in the base of the switch to allow customers to find the switch in the darkness. (Lightbulbs, 2014).

Figure 2-13 Illuminated Switch (Source: Architonic, n.d.)

2.2. Light Bulbs

Every building has light bulbs installed in it. Without light bulbs, we cannot see properly in the dark at night. At a glance, all light bulbs look the same, but actually if we look farther, there are many types of light bulbs available in the market. Different types of light bulb offer different lighting moods, strengths and energy efficiencies.

Incandescent Light Bulb: Incandescent is the most commonly used light bulb and usually the least expensive. It contains argon gas and a very fine tungsten filament and breaks easily if the bulb is shaken or dropped and works by passing the electricity through the filament which glows and heats up to reach a temperature of over 2000^{o}C. Even though Incandescent Bulb does not contain mercury, US Congress passed the Energy Independence and Security Act requiring new energy-efficient standards for basic light bulbs that all standard 100-, 75-, 60- and 40-watt Incandescent Bulbs are being phased out and will no longer be produced but standard Incandescent Bulbs will still be available to purchase (Lowe's, 2014). Incandescent

Bulbs can also be used with a dimmer switch and usually last between 700 to 1,000 hours, not as energy efficient as other options (HGTV, n.d.).

Halogen Light Bulb: This type of light bulb is almost the same like Incandescent Light Bulb by using a filament that is heated to turn on the light, do not contain mercury, and dimmable (Lowe's, 2014). Halogen Light Bulb can last longer than Incandescent Bulb even though it is quite more expensive and burn at a higher temperature (HGTV, n.d.).

Fluorescent Light Bulb: This type of light bulb is filled with mercury vapor that emits UV light when electricity is applied and the UV light will be turned into visible light with a help from coating inside the light bulb, but Fluorescent Light Bulb will not work without a ballast (Lowe's, 2014). Fluorescent Light Bulb produces more light and lasts longer than Incandescent Bulb but unfortunately, Fluorescent Light Bulb cannot be dimmed (HGTV, n.d.).

CFL (Compact Fluorescent Bulb): CFL consumes a quarter of the energy that incandescent bulbs do and last 10 times longer, but CFL is not recommended to be used at workshop because CFL may not hold up to the stress of power surges and CFL contains trace amounts of mercury that customers still need to be aware to prevent breakage and recycle it when it burns out (HGTV, n.d.). CFL is available to be used with a dimmer switch.

LED (Light-Emitting Diode) Light Bulb: LED Light Bulb is a lighting technology that uses tiny light sources called LEDs. LED Light Bulb is available to be used with a dimmer switch. LED Light Bulb is long-lasting and extremely energy-efficient and not like Incandescent, Halogen, and Fluorescent Light Bulb, the heat produced in LED Light Bulb is absorbed into a heat sink, it makes LED Light Bulb keeps cool to be touched (HGTV, n.d. and Lowe's, 2014).

2.3. Silicon Labs C8051F340 Microcontroller

Microcontroller is a single chip that contains the processor (the CPU), non-volatile memory for the program (ROM or flash), volatile memory for input and

output (RAM), a clock and an I/O control unit built in together to deal with specific tasks and mainly used to handle products that require a degree of control exerted by the user ("Microcontroller", 2014 and RoseMary, 2012). In terms of microcontroller's bus size, there are 8-bit Microcontrollers, 16-bit Digital Signal Controllers, 16-bit General Purpose Microcontrollers, and 32-bit Microcontrollers. Silicon Labs C8051F340 is an 8-bit microcontroller that processes 8 bits of data in every clock cycle (Silicon Laboratories, 2009). C8051F340 has 48 pins, 12 pins each side. Each type of microcontroller has various speeds. It affects how fast a microcontroller executes any tasks. The speed of a microcontroller depends on its system clock. A higher system clock makes the microcontroller to execute tasks faster. In C8051F340, the maximum system clock is 12 MHz, but there is a special mode that is a clock multiplier, that can multiply the speed into 4 times its original speed. Therefore, by selecting that special mode, microcontroller's speed could hit 48 MHz. C8051F340 has 64 kB internal flash memory to store the program user made and 4352 Bytes RAM for a temporary data storage or to do specific process calculation. As for clock sources, there are internal oscillator, external oscillator, and low frequency internal oscillator. Internal oscillator supports all USB and UART modes. External oscillator allows users to use another crystal, RC, C or clock with 1 or 2-pin modes. Low frequency internal oscillator has 80 kHz speed that will support sleep mode. C8051F340 also supports switching between clock sources on-the-fly. There are five I/O ports available in C8051F340. Each port has 8 pins. They are P0.0-P0.7, P1.0-P1.7, P2.0-P2.7, P3.0-P3.7, and P4.0-P4.7. These I/O ports support USB 2.0 (Universal Serial Bus) communication, UART (Universal Asynchronous Receiver Transmitter) communication, I2C (Inter-Integrated Circuit) communication, SPI (Serial Peripheral Interface) communication, and EMIF (External Memory Interface). In this research, C8051F340 microcontroller is built in EVB-TouchTFT400_v1.0 (see Figure 2-14) microcontroller development board. The development board connects LCD Touch Screen, C8051F340, ZigBee, and other I/O peripherals (i.e. LEDs,

Buzzer, and Buttons). It also provides VCC headers for incoming voltage and GND headers for ground.

Figure 2-14 EVB-TouchTFT400_v1.0 controlled by Silicon Labs C8051F340

2.4. Success Electronic Co., LTD S95361 TFT LCD Touch Display Module

Success Electronic Co., LTD TFT LCD display module is a 3.0'' diagonal full color 262K TFT LCD. As an LCD screen that uses backlight, it is categorized in transmissive LCD. Transmissive LCD is widely used in portable computers or mobile devices. It does provide excellent viewing indoors but would be difficult to be viewed outdoor since direct sunlight overwhelms the backlight ("Transmissive LCD", 2014). Besides having white LED backlight as its display structure, the LCD is also COG (Chip on Glass), FPC (Flexible Printed Circuit), and TP (Touch Panel) type. Shown on Figure 2-15, COG or Chip on Glass is a technology which is embedded the LSI (chip/IC) directly on LCD display to cut the cost and mechanical since COG do not need any PCD board, connectors, etc. This LCD uses R61509V single-chip controller driver. R61509V arranges gate circuits on both sides of the glass substrate layers. It can manage a maximum 240RGB x 432dots graphics display on amorphous TFT panel in 262k colors. The R61509V supports high-speed interface via 8-/9-/16-/18-bit parallel ports as system interface to the microcontroller. In this research, R61509V uses 16-bit parallel ports as the system interface.

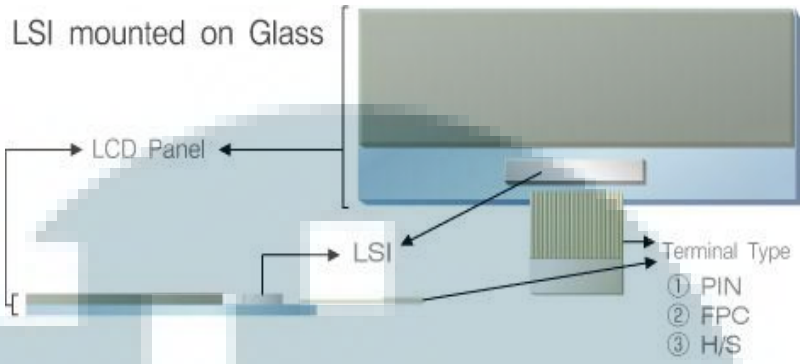

Figure 2-15 On COG, LSI embedded directly on LCD panel (Source: NANOX CORPORATION, 2005)

FPC or Flexible Printed Circuit (see Figure 2-16) is designed as a replacement for traditional wire harnesses by bonding a vast array of conductors to a thin dielectric film (Flexible Circuit Technologies, Inc., 2014a).

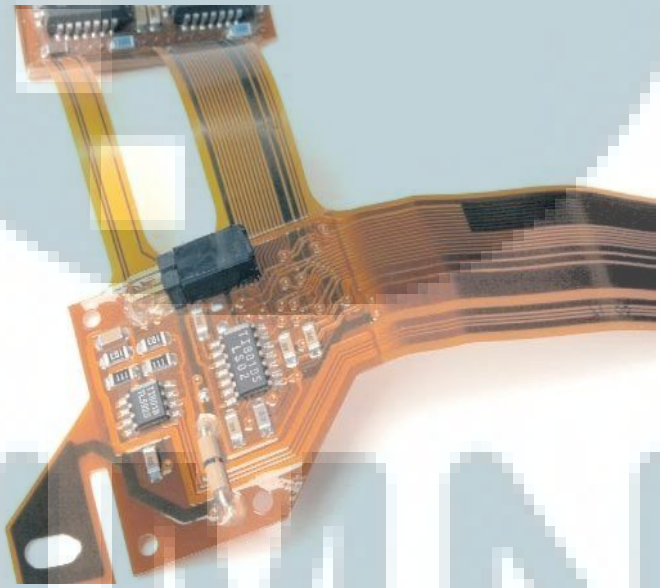

Figure 2-16 Flexible Printed Circuit (Source: Direct Industry, 2014)

There are some primary benefits of flexible circuits compared to traditional cabling and rigid boards include (Flexible Circuit Technologies, Inc., 2014b):

- Assembly Error Reduction

  With accurate designs and automated production, flexible circuits eliminate human errors once involved in hand-built wire harnesses since circuits are only routed to those points called for by the accurate design plan.
- Decreased Assembly Time & Costs

  Flexible circuits eliminate the high cost of routing, wrapping and soldering wires. Complete interconnection systems are installed or replaced, rather than individual hard PC boards. Wiring errors are eliminated and hence manufacturing costs are reduced.
- Design Freedom

  Unlike rigid boards, flexible circuits are not restricted to two dimensions. Because they are as flexible as wires or ribbon cables, flexible circuit design options are endless.
- Flexibility during Installation

  Flexible Circuits allow a third dimension to work with because they can interconnect between two or more planes during execution. As a result, they solve space and weight problems unmatched by rigid boards. Flex circuits can be manipulated many times during installation and execution without electronic failure.
- Improved Airflow

  Flexible circuits, because of their streamlined design, allow for the flow of cooling air through an electronic application.
- Increased Heat Dissipation

  Thinner design of flexible circuits allows for heat dissipation from both sides of the circuit.

- Increased System Reliability

  In the past, most circuit failures occurred at an interconnection point. Flexible circuits can be designed so that interconnections are reduced, which in turn, increases a circuit's reliability.

- Reliability and Durability

  The flexible circuit can move and flex up to 500 million times without a failure. The exceptional thermal stability of polyimide also allows the circuit to withstand applications with extreme heat.

- Package Size and Weight Reduction

  Multiple systems in rigid boards create more weight and utilize more space. Thinness flexible circuits allows for a more streamlined design, eliminating the need for bulky rigid boards. The elasticity and flexibility allow package size reduction.

As a touch panel, the LCD is a resistive single-touch screen panel. This resistive touch screen works on the basis of a single pressure applied to the screen. Therefore, it will not respond any multi-touch input. Ockenden (2010) stated that resistive touch screens consist of a number of layers with the front surface or the first layer is made of scratch-resistant that is an underside conductive material thin film (usually Indium Tin Oxide or ITO) printed flexible plastic and a second layer beneath it is usually made of glass or sometimes hard plastic which is also with a coating of ITO. Resistive touch screens sense any pressure. When the screen is pressed, the first layer will push the next layer, the two ITO films will meet, and the resistance of both layers at their point of contact will be measured (Catanzariti 2010 and Ockenden 2010). Resistive touch screens can be operated with a finger, a fingernail, a stylus or any other object.

2.5. Light Dimmer

Light dimmer is a control that regulates light's brightness levels by essentially cutting some parts of the AC voltage's waveform since the brightness of the lamp is determined by the power transferred to it, the more the waveform is chopped, the more it dims (Sprags 2014). There are some advantages by using light dimmer. Light dimmer will make customers more convenience by giving the right lighting ambience to the room according to customers' mood or taste. Light dimmer can save the energy light bulb consumed and extend the bulb's life. The light levels can be reduced by over 10% before the brightness' reduction is noticed. It is because of the human eyes could perceive light non-linearly. By reducing it over 10%, customers could save nearly 10% in energy consumption. While reducing 50% in dimming levels, customers would save around 40% of the energy. Intelligent dimmers will fade the lamp to a preset level from its current brightness level. Fading the lamp to the preset level, which is also known as soft start, is quite important when the lamp is first turned on. Soft start would extend light bulbs' life considerably. By dimming it 10%, the lamp will last twice than before. While dimming it 50% it will last 20 times than before. Besides, there is also voltage stabilization in more expensive dimmers that will protect the lamps against spikes and peaks in mains voltage. However, light dimmers tend to become warm or even become hot when the load driven by dimmers gets above 250 watts, especially after three or four hours. Light dimmers use a triac or thyristor which is a semiconductor, like a transistor, as its power control device. It varies the amount of electricity it can pass. When the electricity flows through the triac, heat would be built up and it must be dissipated to somewhere else which is mostly dumped into the metal mounting bracket and transferred to the light switch cover plate. However, as long as the load's total wattage is below the rating printed on the dimmer, it is still safe to be used.

2.6. ZigBee

Burchfield, Venkatesan, & Weiner (2007) stated that 'ZigBee is a robust wireless communication standard managed by the ZigBee Alliance and based on the standard IEEE 802.15.4 physical and MAC layers'. ZigBee works on frequency 2.4GHz. The characteristic of ZigBee are reliable, cost-effective, low-power, self-healing, wirelessly networked monitoring and control platform, and flexible coverage. Therefore, ZigBee is targeted to be used in home, business and factory automation applications. Every ZigBee's node has 64-bit EUI (Extended Unique Identifier) known as extended address which is fixed by IEEE. IEEE appoints a unique extended address for each node. Therefore, there will not be two or more nodes having the same extended address. When a ZigBee enters a personal area network (PAN), it will get a 16-bit address, known as network address. A ZigBee could have a different unique network address whenever it enters different PAN. However, there will not be two or more ZigBee having the same network address in the current PAN. ZigBee can handle larger applications because of its multi-hop routing capabilities with mesh networking. If the device to be controlled is out of the reception range, then other intermediate ZigBee nodes will cooperate to route packets to the final target. Mesh networking is great to increase ZigBee's reliability and expand its reception range. Besides, it makes the communication flexible as it may change routes as nodes fail or relocate. To increase reliability on transmitting data, ZigBee uses CSMA-CA (Carrier Sense Multiple Access Collision Avoidance). Therefore, before transmitting data, firstly ZigBee will listen to the channel. If the channel is clear, ZigBee can transmit the data. It will avoid any data collision which will lead any damaged or lost data. Besides, to guarantee sent data's validity, ZigBee uses 16-bit CRC (Cyclic Redundancy Check) which is called FCS (Frame Checksum) (Kurniawan, 2013).

2.7. Home Automation Technology

Home automation has been around for a while and there have been numerous developments and sophisticated modern features to manage comfort, security, and entertainment (Lyon, 2010). There are some physical types of home automation technology: wired, wireless, and hybrid.

Wired Home Automation Technology can be called powerline. The device communicates with other home automation products through home electrical wiring. X10 and UPB (see Figure 2-17 and Figure 2-18) are known samples of wired home automation technology.

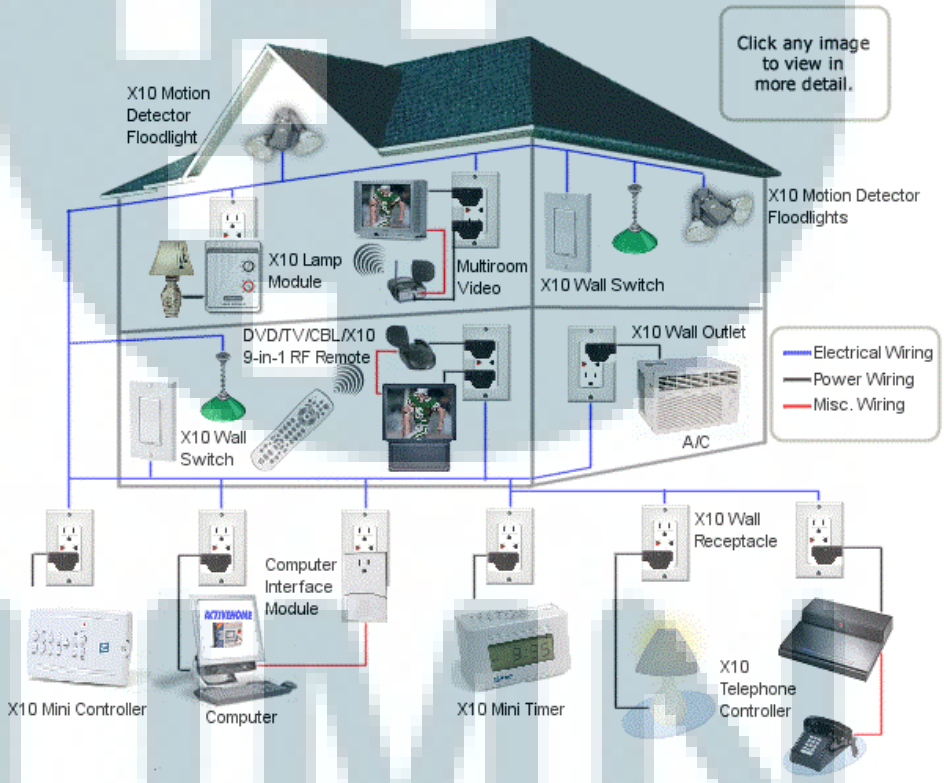

Figure 2-17. X10. (Source: Interior Images, n.d.)

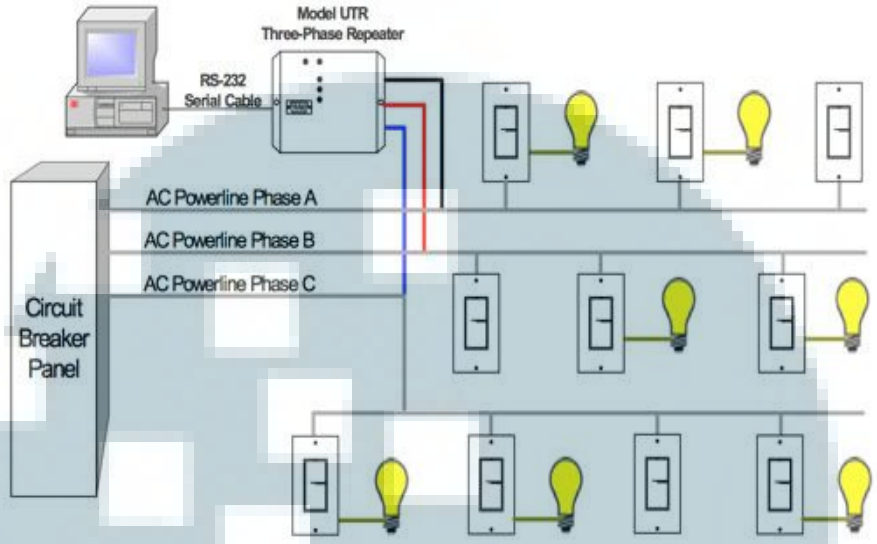

Figure 2-18 UPB (Source: Home Controls, 2014)

At present, the common wireless communication protocols include Radio Frequency Identification (RFID), ZigBee, Infrared Data Association (IrDA), Bluetooth and Wi-Fi. **Wireless Home Automation Technology** usually uses RF (Radio Frequency) communication (e.g. Z-Wave, ZigBee) and Wi-Fi as its protocol. The performance comparison among ZigBee and Wi-Fi is shown in Table 2-1 (Huang et al., 2011).

Table 2-1 Performance comparison among ZigBee and Wi-Fi (Source: Huang et al., 2011)

Characteristics	ZigBee	Wi-Fi
IEEE standard	802.15.4	802.11 a/b/g
Max signal rate	250 kb/s	54 Mb/s
Nominal range	10–100 m	100 m
Max number of nodes	>65,000	2007
Power consumption	Low	High
Protocol complexity	Simple	Complex
Cost	Low	High

Shown in Table 2-1, Wi-Fi has much more signal rate compared to ZigBee. It makes Wi-Fi transfer data faster than ZigBee. However, even though ZigBee has less speed than Wi-Fi, ZigBee works with low power and requires lower cost than Wi-Fi.

Wireless home automation has some benefits compared with powerline technology. By using wireless control devices, customer can do electrical planning, move the devices after installed, or even expand the system flexibly since the device can be placed where they are needed without limitation imposed by wiring, including areas that are difficult to wire and wireless home automation can eliminate the need for wiring and other raw materials to save labor and material cost and the system can be installed more quickly with no damage to walls or ceilings (Dilouie, 2011). The wireless control devices utilize batteries or energy harvested from the operating environment as their power. Devices in wireless home automation technology work together in the same way like they would do in a wired home automation technology. The different is how the devices interact and the intelligence's level needed. While in a hardwired system, the devices intended to work together can be simply wired, however, in a wireless system, the devices must be programmed or mapped to each other so they know to which control signals they should be responsive, and how they should respond (Dilouie, 2011).

Hybrid Home Automation Technology is a technology where wireless products work together with powerline systems through the use of bridge devices. Currently, INSTEON is the only integrated technology that communicates via both powerline and wireless technologies, while powerline devices transmit data at 131.65 KHz and corresponding wireless devices at 904 MHz (Fritz, n.d.). The devices simultaneously send out data using powerline and wireless protocol in peer-to-peer fashion within 50 meters. INSTEON uses mesh topology (see Figure 2-19) that is known as "dual mesh" or "dual band mesh" (i.e. INSTEON powerline protocol, the INSTEON radio frequency (RF) protocol, or both) networking to improve the robustness of the network by minimizing reliance on central devices (Fritz, n.d.).

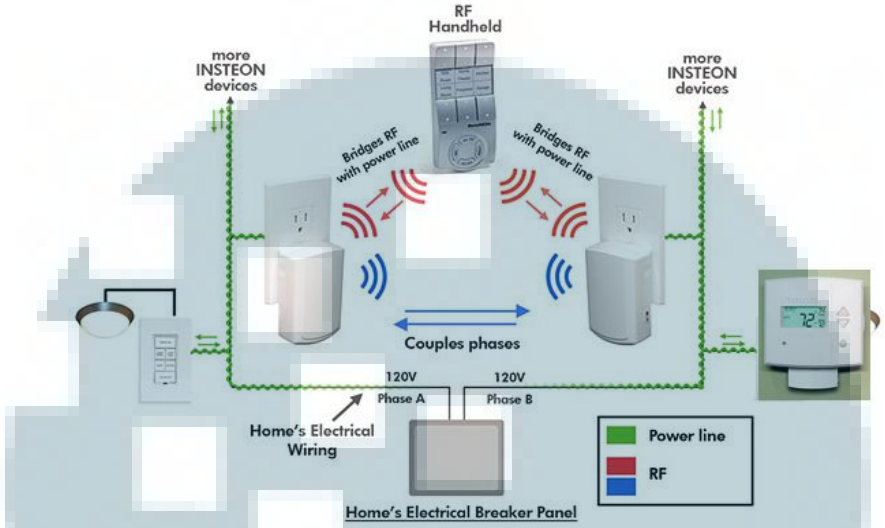

Figure 2-19 INSTEON dual mesh topology (Source: Netropolus Smart Home Automation, 2013)

With home automation technology, customers could control lights, electrical outlets, fans, shades, thermostats, security systems, door locks, etc in a blink of an eye. Even more, customers can control their home from a wireless remote control, a wall-mounted keypad in a bedroom or via Internet connected smart phone/tablet/computer from anywhere in the world. Smart Home (2014) stated some benefits of home automation technology to ease customers' life.

Convenience: Home automation provides the customers control, alert, and automation to the appliances at home even though customers are still sleeping or even away from home. By automating the appliance (e.g. lights), customers can adjust the room's atmosphere based on their preferences and system will repeat the light preferences on the next days.

Safety: Home automation technology can remind or alert the customers to emergency events that customers should know immediately even while the customer is away from home. An automated home keeps properties under surveillance so customers can react at a moment's notice.

Energy Savings: Not all lamps are dimmable, some like compact fluorescent lamps, can only be switched on or off, however, energy can still be saved even if they are turned off automatically when not required. With home automation technology, unused lamps can be turned off automatically. System also can dim the lamps to lower brightness automatically based on customers' preset or sensor attached on the system. By turning off the unused lamps and dimming the lights, home automation will help customers to save the energy.

Fun: Home automation gets customers involved by allowing the customers to set their personal preferences and actions, then sit back and enjoy using the latest in home automation technology.

2.8. Previous Research

There are some major manufacturers who had developed wireless dimmer switch panels. They are Lutron Electronics, Inc., Wattstopper, and Leviton.

Lutron Electronics, Inc. has developed some wireless dimmer switch panel system that is called HomeWorks QS. Some Lutron's devices that are using HomeWorks QS are Dynamic Keypad, Maestro Wireless seeTouch Keypad, Maestro Dimmer, GRAPHIC Eye QS, Tabletop Keypad, Pico Wireless Control, and Car Visor Control (Lutron Electronics Co., Inc., 2014a). **Dynamic Keypad** (see Figure 2-20) is using LCD touch screen to display and control lights, shades, etc in the rooms. Customers can set the brightness level of the lights and light's presets. **Maestro Wireless seeTouch Keypad** on Figure 2-21 is a panel with some lighting's and shades' option buttons or even presets customers chosen. At the beginning, customers can customize the buttons and its names in accordance with their needs. It can be four buttons in a row and dimmer buttons at the bottom or just two buttons in a row. Each button in Maestro Wireless seeTouch Keypad has a LED indicator to inform customers which light is on or off. Shown in Figure 2-22, **Maestro Dimmer** is a simple wireless dimmer switch panel from Lutron. It looks like a conventional rocker switch panel but it has a dimmer on the right side of the button. There are some LED indicators on

the left side of the button to inform the customer light's brightness level. Maestro Dimmer only can control one light in one switch panel. **GRAPHIC Eye QS** in Figure 2-23 is more complex than the rest HomeWorks QS' devices. By combining LCD touch screen and buttons, GRAPHIC Eye QS controls up to 16 lighting zones and up to 3 shade zones in conference rooms, restaurants, home theaters, classrooms and more (Lutron Electronics Co., Inc., 2014b). GRAPHIC Eye QS is also equipped with a LED indicator besides each button. Dynamic Keypad, Maestro Wireless seeTouch Keypad, Maestro Dimmer, and GRAPHIC Eye QS are wired on the wall for power supply and control wiring. Devices that are compatible with HomeWorks QS can be used together or when customers need more keypads to control the lights, shades etc. but customers have to be aware whether they need to add external power supply to the system, since HomeWorks QS is only able to support up to +12VDC. To be able to access the switch panels from far, customers can use Tabletop Keypad, Pico Wireless Control, and Car Visor Control. **Tabletop Keypad** in Figure 2-24 looks like Maestro Wireless seeTouch Keypad. Tabletop Keypad has many buttons on it with a LED indicator besides each button.

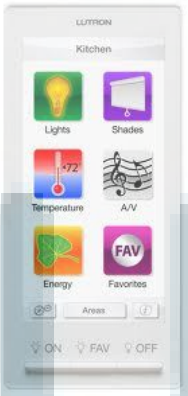

Figure 2-20 Lutron Dynamic Keypad
(Source: GreenTech Advocates, 2010)

Figure 2-21 Lutron Maestro Wireless seeTouch Keypad
(Source: Lutron Electronics Co., Inc., 2014)

Figure 2-22 Lutron Maestro Dimmer (Source: Lutron Electronics Co., Inc., 2014)

Figure 2-23 Lutron GRAPHIC Eye QS (Source: Lutron Electronics Co., Inc., 2014)

Pico Wireless Control (see Figure 2-25) has the same function like Tabletop Keypad but it can handle only one appliance, either a light or a shade. It means customers would need more than two Pico Wireless Controls if there are two lights to be controlled. **Car Visor Control** in Figure 2-26 is a remote that customers can use when they are going out. There are three options that are Home, Away, and Garage. If customers choose Home button, the system will set the lights, shades, etc at home like the preset customers expected when they arrive at home. Same like Home button, when Away button chosen, the system will set the lights, shades, etc at home like the preset customers expected when they leave their house. Garage button controls garage doors. Since all HomeWorks RF devices must be located within 30 feet (9 m) of a hybrid repeater or an RF Processor (Lutron Electronics Co., Inc., 2014c), Lutron provides an RF repeater, known as **HomeWorks Hybrid Repeater** (see Figure 2-27). Each hybrid repeater covers approximately 2,500 square feet (232 m^2) of living space and up to four repeaters can be added to each RF processor.

Figure 2-24 Lutron Tabletop Keypad (Source: Lutron Electronics Co., Inc., 2014)

Figure 2-25 Lutron Pico Wireless Control (Source: The Home Depot, 2013)

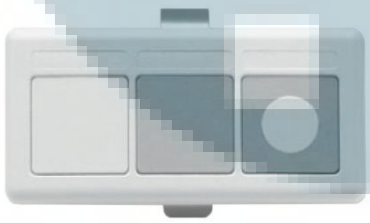

Figure 2-26 Lutron Car Visor (Source: World Wide Stereo, n.d.)

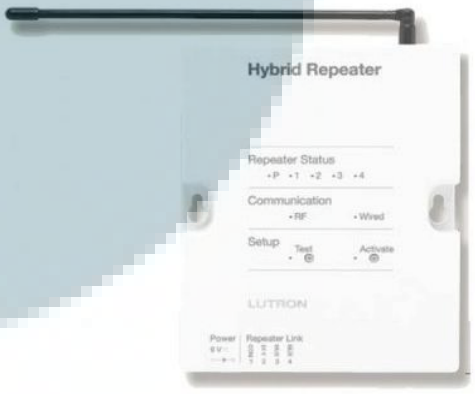

Figure 2-27 Lutron HomeWorks Hybrid Repeater (Source: Lutron Electronics Co., Inc., 2014)

Wattstopper launched many types of wireless dimmer switch panels. The switch panels are classified by the type of the light bulbs and how the customers control the lights. There are switch panels only for CFL/LED Bulbs, only Incandescent Light Bulbs, only Fluorescent Light Bulbs, only Incandescent and Fluorescent Light Bulbs, or even Universal Light Bulbs. Universal dimmer switch panels can control any kinds of dimmable light bulbs. There are switch panels controlled Architectural Dimmers, Touch Dimmers, Slide Dimmers, Paddle Dimmers, Dimmer Sensors, and Touch

Remote. **Architectural Dimmer** switch panel in Figure 2-28 allows customers to label the switch and it has an on/off button and a slider for the dimmer. **Touch Dimmer** switch panel in Figure 2-29 allows customers to turn on/off and dim the light with sliding the touch panel on the switch. **Slide Dimmer** switch panel in Figure 2-30 allows customer to set the dimmer through a slider and there is also an on/off button on the switch. Shown in Figure 2-31 **Paddle Dimmer** switch panel allows customers to turn on/off the light by paddling the switch and sliding the slider beside the paddle to set the dimmer. **Dimmer Sensor** switch panel uses Passive Infrared (PIR) Occupancy (see Figure 2-32) and Vacant Sensor (see Figure 2-33) to turn on/off the light.

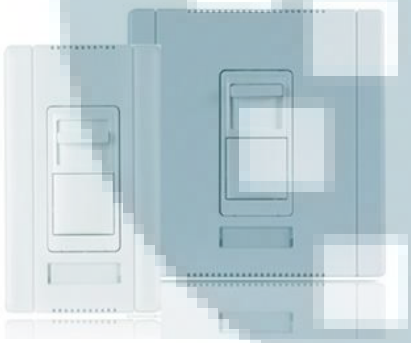

Figure 2-28 Wattstopper Architectural Dimmer switch panel (Source: WattStopper, 2014)

Figure 2-29 Wattstopper Touch Dimmer switch panel (Source: WattStopper, 2014)

Figure 2-30 Wattstopper Slide Dimmer switch panel (Source: WattStopper, 2014)

Figure 2-31 Wattstopper Paddle Dimmer switch panel (Source: WattStopper, 2014)

Figure 2-32 Wattstopper Dimmer PIR Occupancy Sensor switch panel (Source: WattStopper, 2014)

Figure 2-33 Wattstopper Dimmer PIR Vacant Sensor switch panel (Source: WattStopper, 2014)

Leviton offers various wireless dimmer switch panels from residential to commercial demands. For commercial demands, Leviton offers an 8-scene control in a press button (Leviton Manufacturing Co., Inc., 2014b), known as **Luma-Net 400 CP Series** (see Figure 2-34). It will help customers to change the lighting atmosphere without wasting much time. Leviton also offers **CP Stations** (see Figure 2-35) and **Luma-Net 800 CP Series** (see Figure 2-36) which are some slide switch panels that can dim up to eight light bulbs. CP Stations is like a simple 5-slider while Luma-Net 800 CP Series can handle up to 8 light channels with on/off programmable scenes. Leviton also offers **Dimension D4000** (see Figure 2-37) which is a complete system that can control 32 channels and have 18 scenes memory. For residential demands, Leviton only offers one dimmer switch panel for one light bulb with various button's style, either toggle, slide, rotary dimmer, touch, or rocker switch. However, there is only one RF dimmer switch panel provided by Leviton, known as **Vizia RF+** (see Figure 2-38). Vizia RF+ series includes Vizia RF+ Scene Capable Dimmer Plug-in, Vizia RF+ Scene Capable Dimmer, Vizia RF+ LCD Display Remote Control, and Vizia RF+ Scene Wall Controller.

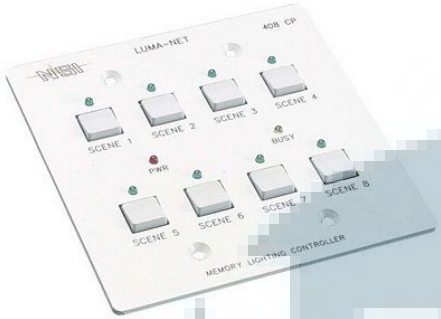

Figure 2-34 Leviton Luma-Net 400 CP Series (Source: Stage Lighting Store, 2014)

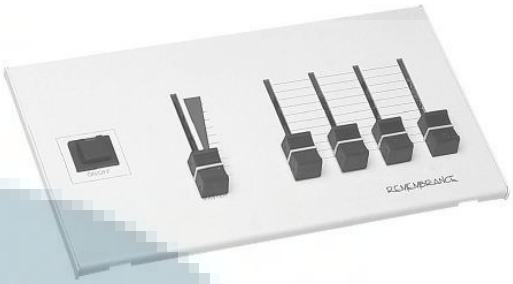

Figure 2-35 Leviton CP Stations (Source: B&H The Professional's Source, 2014)

Figure 2-36 Leviton Luma-Net 800 CP Series (Source: Leviton Manufacturing Co., Inc., 2014)

Figure 2-37 Leviton Dimension D4000 (Source: Leviton Manufacturing Co., Inc., 2014)

Figure 2-38 Leviton Vizia RF+ series includes Vizia RF+ Scene Capable Dimmer Plug-in, Vizia RF+ Scene Capable Dimmer, Vizia RF+ LCD Display Remote Control, and Vizia RF+ Scene Wall Controller (Source: Leviton Manufacturing Co., Inc., 2014)