Mood & Hue Light Source Design Using IoT

A thesis submitted in fulfilment of the requirements for the degree of
Master of Engineering
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Submitted by

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All information in this document have obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have cited and referred all materials and results that are not original to this work.

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Abstract

The colour of lighting can have a huge impact on the way it is received and therefore it has effects on the human body. Different levels of brightness and lighting temperature can trigger different emotions. Some people may even find that they associate certain rooms with being in a particular mood, e.g., always feeling anxious in a room, without realizing that it is caused by the type of lighting used. This problem can be negated by installing Mood Lighting but, very few lighting solutions are there which provide mood lighting and those who provide, they charge much higher than the nominal lighting charges. Here in this thesis work, one Light Emitting Diode (LED) lamp has been developed, which provides 16 million different colours to choose from and has specified colour codes for each mood. The Corelated Colour Temperature (colour) and illuminance level (in lux) can be controlled using any device which supports webpage. Here no separate application needs to be installed, just a web browser is needed (as every computer laptop and smartphone has a web browser). It doesn't even require internet connection to control the LED bulb. All these features come under a very less price as compared to the commercially available lamps. Apart from that, the main benefit of having a mood lighting setup is that it reduces the amount of energy consumed, hence lowering the electricity cost. This thesis also described how each colour and its brightness can affect the mood of human being.

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CHAPTER 1

INTRODUCTION

1. Introduction

1.1. General Introduction

“Do I really need to get a mood lighting setup? I already have enough lights to light up the room.” A valid thought in every house owner’s mind. Well, different people see their homes differently. Some see it as their sanctuary, some might see it as a party pad and some might see it as place to kick back and relax after a long day's work.

Whatever it may be, with the help of mood lighting that effect can be created in the house. Mood lighting highlights and enhances any space dramatically, and make the home look much nicer and more inviting.

Apart from that, the main benefit of having a mood lighting setup is that it reduces the amount of energy consumed, hence lowering the electricity cost. It also helps release stress, enhance mood and increase motivation.

Smart lighting is a common entry point for home automation, but what’s the point of upgrading to mood lighting in the first place? In common with most smart devices, lighting makes the life safer and easier. Making the house look occupied, even when the residents are on vacation, adds a powerful layer of security to the home. Controlling the lighting either remotely in-app or using voice commands puts convenience at uppermost.
Smart lighting can be used for more than just utilitarian tasks and automation, though.

Then their practical implementation tasks started, and it was found that, big industries do conduct research on mood lighting as well as hue lighting, but the cost at which they do this comes with huge risk factor of failing in the initial stages. That's why only big and well-established industries try out this research and implement on field. But again, as it costs too high, companies usually charges much more than the nominal lighting charges. That's because, they need to provide a mobile application to control the light as well as maintain the software of the application, for which they need to either open a software engineer/developer branch along with their main lighting solutions branch or they need to find a vendor who will maintain the software/application part totally at their end. Typically, a single android app development costs lakhs of rupees, and again lakhs of rupees go every month in its maintenance. But only android app will limit their market sale, so they need this application for IOS to i.e., for iPhone users. And along with smartphone applications they need a web application to, which can either be software for windows or web-application. All this sums up in cores of rupees to begin with and there is a high change of not getting a market kick-off. This thesis work will solve this problem.

The main problem resides with the software that they provide to control the light. This thesis work solved this problem along with adding some special features to it.

There is a readymade software & application available for free to control these devices, but again this application comes with the problem of login and also consumes to much space on our smartphones. Now they also have removed the free buttons and widgets from that app, people need to buy subscription to use them, every single month. Then there comes our web page, which consumes absolutely no space in the user's device and no login issues and also without internet.

In this thesis the effects of mood lighting are studied in various zones created in the home according to the occupying pattern in that space.

By analysing some previous studies and market capitalization about mood & hue lighting, it can be stated that this lighting sector is very underutilized and also cost inefficient. So, with some study a Wi-Fi controlled LED bulb has been developed which can be operated using a webpage without internet. This is achieved through a Wi-Fi module ESP8266 IoT device.

Here a RGB LED is used, which takes input as 0 to MAX in each leg (RGB LED has 4 legs, 3 legs for R, G & B and 1 for GND). But computer/smartphone understands colours as 'rgb(255, 255, 255)' = white, which is the maximum output which can be provided by the RGB LED. Varying the values from 0 to 255 of each 'r', 'g' & 'b' in above will result in different colour combinations. These 'rgb' values then transferred to the NodeMCU, then it will be calibrated into 0 to MAX format and then will be given to each leg of the RGB LED.

All the necessary codes for the web page design and controlling functions are been embedded into the IoT device itself. It not only provides lighting condition for different moods but also can be used to produce any colour from 16 million different colours and of course the brightness of each colour can be adjusted as per our need. The mood lighting guide helps the user to understand use of each and every colour shade relating to the mood.

1.2. Literature Survey

<u>Study Paper 1:</u> "The impact of lighting on mood" [1] by C L B McCloughan BSc PhD, P A Aspinall MSc PhD and R S Webb BEng MSc CEng FCIBSE Environmental Studies Faculty, Edinburgh College of Art, Edinburgh, UK Department of Building Engineering and Surveying, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, UK:

Summary: Reports of the effects of lighting on mood are mainly at an anecdotal level There is little by way of empirical support and the existing evidence is problematic and contradictory. This experimental study shows that there are systematic influences of lighting on mood from lighting parameters within the range of those encountered in everyday interior conditions. The nature of the lighting effects is complex and is best summarised as initial effects and longer-term effects. Initial effects link illuminance with sensation seeking and correlated colour temperature (CCT) with hostility. Longer-term effects involve complex interactions between gender, illuminance and CCT. The results are consistent with Keller's proposal for short-term and long-term lighting effects.

Study Paper 2: Lighting to Make You Feel Better: Improving the Mood of Elderly People with Affective Ambiences [2] by Andre Kuijsters, Redi, Boris, and Ingrid Heynderickx PLoS One. 2015; 10(7): e0132732. Published online 2015 Jul 20.

Summary: Current lighting technologies extend the options for changing the appearance of rooms and closed spaces, as such creating ambiences with an affective meaning. Using intelligence, these ambiences may instantly be adapted to the needs of the room's occupant(s), possibly improving their well-being. The authors have hypothesized that ambiences with a clearly recognizable, positive affective meaning could be used to effectively mitigate negative mood in elderly. After inducing a sad mood with a short movie one group of elderly was immersed in a positive high arousing (i.e., *activating*) ambience, and another group in a neutral ambience. Similarly, after inducing anxiety with a short movie one group of elderly was immersed in a pleasant low arousing (i.e., *cozy*) ambience, and another group in a neutral ambience. They monitored the evolution of the mood of the four groups of elderly over a period of ten minutes after the mood induction, with both self-reported mood measurements (every 2 minutes) and constant measurements of the skin conductance response (SCR) and electrocardiography (ECG). In line with the hypothesis, it has been found that the activating ambience was physiologically more arousing than the neutral ambience. The cosy ambience was more effective in calming anxious elderly than the neutral ambience, as reflected by both the self-reported and physiological measurements.

Code of Ethics of the Dutch Institute for Psychologists, and by the ethical committee (ICBE) of Philips Research, following the Declaration of Helsinki, in 2013. All participants gave written informed consent.

Study Paper 3: Smart lighting systems: State-of-the-art and potential applications in warehouse order picking February 2021International Journal of Production Research 59 [3].
Project: Use Cases and Potentials of Smart Lighting Systems in Industrial Settings Authors: Marc Füchtenhans, Technische Universität Darmstadt. Eric Grosse, Universität des Saarlandes. Christoph Glock, Technische Universität Darmstadt.

Summary: Artificial lighting is a constant companion in everyday private and working life, influencing visibility in interior spaces as well as outdoors. In recent years, new technical solutions have extended traditional lighting systems to become ‘smart’. Different types of smart lighting systems are available on the market today, and researchers have concentrated on analysing their usability and efficiency, especially for private households, office buildings and public streets. This paper presents a systematic literature review to analyse the state-of-knowledge of technologies and applications for smart lighting systems. The results of the review show that smart lighting systems have been frequently discussed in the literature, but

that their potentials in industrial environments, such as production and logistics, has rarely been addressed in the literature so far.

Lighting systems for industrial environments often have very different requirements depending on the working environment and operating conditions. Based on the results of the literature review, this paper contributes to closing this research gap by discussing the usage potential of smart lighting systems to improve the efficiency of warehouse order picking, which is an application that may benefit from various functions smart lighting systems provide. Several propositions are developed that emphasize research opportunities and managerial implications in this context.

Study Paper 4: Lighting in the Workplace as the Visual Environment That Affect the Occupant's Mood [4]: A Literature Review by Silfia Mona Aryani, Arif Kusumawanto Jatmika Adi Suryabrata, Department of Architecture and Planning, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia.

Summary: Lighting in the workplace is often assessed based on functionality. In line with scientific development, the research into lighting observes its effect on the occupant's health and psychology. This article discusses research publications related to the relationship between artificial lighting and mood, by reviewing relevant literature from journals, dissertations, theses, and books from the last 10 years. Some of the literature refers to the older sources; hence the study is expanded to cover, in certain cases, a publication period of more than 10 years ago.

The first section of this review discusses the general definition of mood and its role in the workplace. The next section explains the visual requirements of a workplace environment, especially regarding the required standards and the lighting's effects on health. The third section of the paper discusses the relationship between the visual environment and mood, with particular reference to how lighting enters and affects mood. The final section of this discussion addresses previous research related to the visual environment and mood that can be categorized into three focal points:

(i) Illuminance level effects;
(ii) Correlated colour temperature effect, and
(iii) Mixed influencing factors.

Literature Survey conclusion -

- In all the previous works, relevant researches and previous works, there are experiments conducted on humans for identifying the change in behaviour when exposed to different lighting conditions. The results are simple, that coloured lighting dominantly intervene with the mood. So, knowing correct lighting condition for a particular mood is very important in order to implement those in practical field. Mood Lighting is always a very underutilized sector. From theory papers to practical implementations is a long road to go. This is the main problem with mood lighting, not in the concept not in the practical approach, but in the industries itself. Industries think this field is not much in demand and rather requires so much research and money to begin with. And there are even few industries which actually provide mood lighting in Hue lighting system installation, but charges too much when compared to nominal lighting installation because of the app they use. Their app is so good and well designed by industry experts for smooth control. But problem is that the one who wants to control those lights must have their apps installed in their smartphone and eats up too much storage space and requires internet connection which is too much complex for a simple lighting control mechanism

1.3. Problem Identification

In this thesis work to develop a RGB LED bulb using simple and easy control mechanism and which doesn't even require the need of installing any application and internet connectivity. The lamp can be operated by some simple steps like plug-in, connection to the Wi-Fi and opening the browser.

1.4. Objectives

The main objectives of this thesis are:

- To develop a real-world prototype of Mood & Hue lighting using a LED bulb which can be controlled through a smartphone without the need of internet connectivity.

- To helps people to understand the importance of Mood Lighting in their life, and the science behind the human behaviour(mood) associated with each colour.

- This model can also be used as a Hue lighting system for decoration of indoors and outdoors as per user's need and colour choice (of 16 million different colours) along with desired brightness level.

1.5. Methodology

- Estimation of lighting requirements i.e., CCT and illuminance level suitable for a particular mood.

- Analysis of the risk factor associated with each colour, that how a particular colour at a particular lighting level could harm human skin and eyes.

- Development of a single webpage from which the LED bulb can be controlled smoothly without any need of internet connectivity.

- To design the program in such a way that it should work in synchronism with the hardware.

- To upload the whole program into the Wi-Fi module which is NodeMCU model ESP8266.

- Selection of proper calibrated input as well as output.

- To develop the Wi-Fi controlled LED bulb as per requirement.

- To control the developed LED bulb using a webpage without internet.

1.6. Outline

- **Chapter 1** - This chapter gives the reader a gist of the topic “Mood & Hue Light Source Design Using IoT, describing the basic idea behind this comprehensive study.

- **Chapter 2** – In this chapter basic understanding of Mood and Hue lighting is been highlighted and how these concepts can be used to develop a better lighting system.

- **Chapter 3** – This chapter gives us insight about the previous lighting methods that has been used in the industry or are still being used. Understanding this chapter is very important as a step in developing own control method.

- **Chapter 4** – This chapter has list of components that can be used, circuit suitable, block diagram to give an rough idea about which part does what and at the end the flow chart, which enables us to fully understand the working procedure as per user’s point of view.

- **Chapter 5** – In this chapter the development of actual circuit takes place, describing how and why each component is been picked, what is its benefit over similar other component that can be used, and then the proper internal working of the device bit by bit, understanding each level of depth along with a suitable flow chart.

- **Chapter 6** – Here in this chapter, two formulas have been described and used to calculate the calibrated output voltage from the input received by the ESP8266 module and then the implementation of these formulas into the code which has been written in C++ language inside the ESP8266 module.

- **Chapter 7** – This chapter is result analysis, here the outcome of this thesis work is been described in only few words along with the practical implementation pictures, which helps understand visually the theme of this thesis work.

- **Chapter 8** – Here the future scope for this long thesis work is been discussed. What holds next in this world of automation and smart lighting, what is the key to expand in this domain and how this can be the future of lighting industry.

CHAPTER 2

MOOD & HUE LIGHTING

2. Mood & Hue Lighting

2.1. How Lights affects mood

Light creates more than just visual effects [5] (image, shape, intensity, perception, contrast, etc.); it also has biological and psychological effects that can impact the health and wellbeing of humans.

When light biologically impacts human body, it can improve or disrupt sleep, cognition and overall wellbeing. It can improve mood and stabilize the circadian rhythms, helping humans get a better and deeper night's sleep. Psychologically, light can decrease depression scores and even increase cognitive performance such as reaction time and activation.

Kaplan and Kaplan: Environmental Cognition –

Rachel and Stephen Kaplan, both former professors of psychology at the University of Michigan, have conducted numerous studies on the way humans react to their environments. For this particular subject of lighting and psychology, a study they published titled "The Experience of Nature: A Psychological Perspective" includes some interesting findings that can help in better understanding of the way light can affect us.

Kaplan and Kaplan found that when humans are exposed to a new environment, humans tend to cognitively try to find a match in our memory that fits the new environment. This helps to interpret and understand a new environment, and might make it seem less daunting or intimidating. Whether it's a building that reminds the humans of a toy they had as a child or a space that resembles something they just saw a few weeks ago – finding familiarity in the unknown help humans adapt.

This is where lighting can come in. It can be used to highlight building elements, spaces, paintings, textures, etc. that people may

Find familiar. A brick wall that resembles one in a café a person frequently visits, or a painting that makes people think of the one in mother's house. Highlighting areas of an environment to help draw people's attention can help them find familiar objects, spaces and structures.

"It is also important that a change in texture or brightness in the visual array is associated with something important going on in the scene. In other words, something that draws one's attention within the scene should turn out to be an important object or boundary…If what draws one's attention and what is worth looking at turn out to be different properties, then the scene lacks coherence." – Kaplan and Kaplan, 1988

Different Factors Affecting Mood –

2.1.1. Brightness and Saturation

These are the three main qualities of light in relation to colour. Brightness is the amount of light given off by a light source, usually expressed in lumens or lux. Some studies have shown that brighter light can intensify emotions, while low light doesn't remove emotions, but keeps them steady. This can lead to people having the ability to make more rational decisions in low light and find it easier to agree with others in negotiation.

Saturation is the intensity of a colour. More saturated hues can have amplifying effects on emotions, while muted colours can dampen emotions. In art, saturation is defined on a scale from pure colour (100% [fully saturated]) to grey (0%). In lighting, a similar scale can apply.

Hue is defined as a colour or shade. It's been proven (through various studies) that natural light can make people happier, but colours created by artificial light can also evoke different emotions and have other effects on the body.

Blue/white light make humans energetic and can interrupt sleep patterns if exposed to around bedtime due to the fact that blue light suppresses melatonin levels. Brain cells tend to be the most sensitive to blue wavelengths and the least sensitive to red wavelengths. Blue wavelengths can even have an impact on those who are blind when it comes to circadian rhythms.

Red/amber light is the least likely hue of light to impact our internal clocks. Red light in the evening can help improve mental health. This is because red light in the evening helps increase the secretion of melatonin which leads to better sleep at night. Better sleep at night leads to improved cognition and overall mental wellbeing.

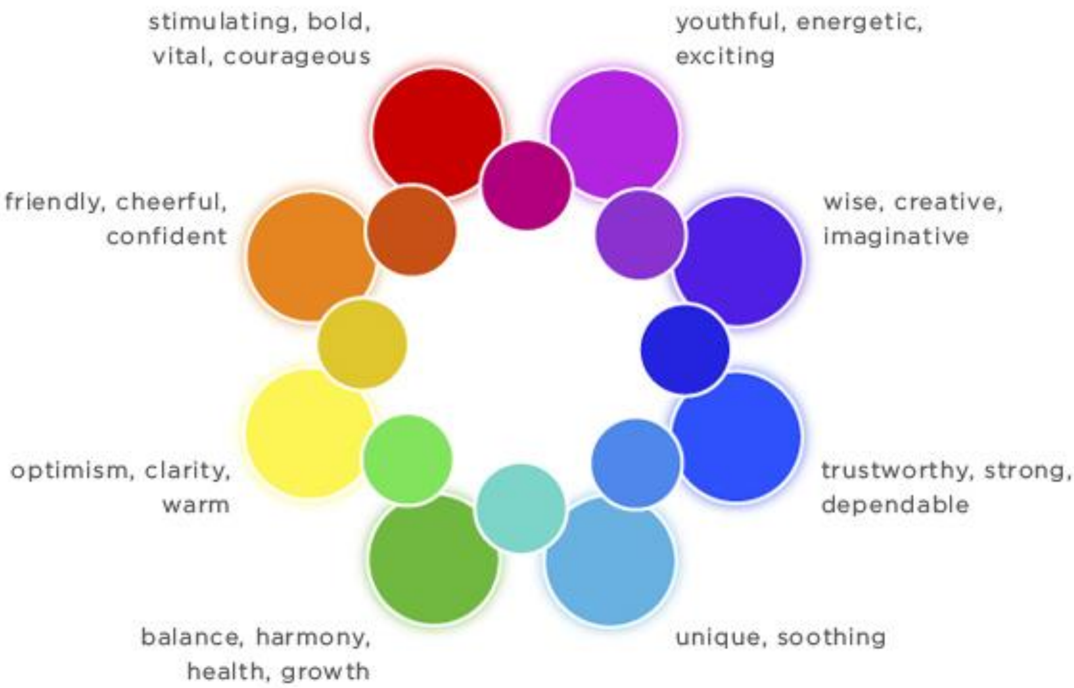

Fig. 1
Psychology of Colour

2.1.2. Circadian Rhythm

Circadian rhythm is our internal clock. It influences melatonin secretion, cortisol activity and alertness. As learned in the previous section, blue light suppresses levels of melatonin, helping humans stay awake and alert, while red light increases levels of melatonin, helping our bodies get ready for bed.

When there is a lack of melatonin, people can encounter sleep problems that can eventually lead to behavioural changes. To sustain healthy levels, stay away from blue-hued light towards the end of the day or when someone are preparing to go to sleep. This will help levels of melatonin rise, giving a better night's sleep.

Circadian rhythms can also affect the limbic system. This system regulates a person’s feelings of happiness, sadness, anger and other emotions. A disrupted rhythm can negatively affect these emotions and more.

2.1.3. Seasonal Affective Disorder (SAD)

SAD is a mood disorder that is caused by symptoms of depression during certain times of the year, usually during the winter. It’s not exclusive to people who have a history of mental illness and can happen to anyone. Some geographic locations have more cases of SAD than others due to the difference in the seasons.

According to the Mayo Clinic, symptoms of SAD include:

- Feeling depressed most of the day, nearly every day
- Losing interest in activities a person once enjoyed
- Having low energy
- Having problems with sleeping
- Experiencing changes in the appetite or weight
- Feeling sluggish or agitated
- Having difficulty concentrating

Light therapy is a common treatment method for SAD. There are many types of light boxes that can be utilized, but essentially, patients are exposed to a bright light within the first hour of waking up every day. Its purpose is to mimic natural light outside, and studies have shown that it can cause a change in the brain’s chemicals, thus impacting mood.

It’s usually very effective for most people with SAD, but if light therapy doesn’t work, medications and other treatments may be appropriate.

2.1.4. Direction of Light

The direction of a light source can transform spaces and impact the way people feel in these spaces. Lighting positioned above eye level can create a feeling of restraint, creating a more formal atmosphere. On the other side, lighting positioned below eye level can provoke a feeling of individual importance, creating a more informal atmosphere.

The chart below (Table - 1) from the Illuminating Engineering Society (IES) shows various lighting effects and how they can impact a space:

Table – 1

Psychological impact on human beings due to direction of incident light

PSYCHOLOGICAL IMPACT	LIGHTING EFFECT	LIGHT DISTRIBUTION
Tense	Intense direct light from above.	Non-uniform
Relaxed	Lower overhead lighting with some lighting at room perimeter, warm color tones.	Non-uniform
Work/Visual Clarity	Bright light on workplane with less light at the perimeter, wall lighting, cooler color tones.	Uniform
Spaciousness	Bright light with lighting on walls and possibly ceiling.	Uniform
Privacy/Intimacy	Low light level at activity space with a little perimeter lighting and dark areas in rest of space.	Non-uniform

Content retrived from IES Light Logic (www.ieslightlogic.com)

2.2. Colour Psychology

The psychology of colour [6] is based on the mental and emotional effects colours have on sighted people in all facets of life. There are some very subjective pieces to colour psychology as well as some more accepted and proven elements. Keep in mind, that there will also be variations in interpretation, meaning, and perception between different cultures.

Did people know that surroundings may be influencing their emotions and state of mind? Do ever notice that certain places especially irritate people? Or that certain places are especially relaxing and calming? Well, there's a good chance that the colours in those spaces are playing a part.

In art therapy, colour is often associated with a person's emotions. Colour may also influence a person's mental or physical state. For example, studies have shown that some people looking at the colour red resulted in an increased heart rate, which then led to additional adrenaline being pumped into the blood stream. The reader can learn more about how colour therapy works and how light and colour might affect us.

There are also commonly noted psychological effects of colour as it relates to two main categories: warm and cool. Warm colours – such as red, yellow and orange – can spark a variety of emotions ranging from comfort and warmth to hostility and anger. Cool colours – such as green, blue and purple – often spark feelings of calmness as well as sadness.

The concepts of colour psychology can also be applied in everyday life. For example, maybe planning on re-painting the walls or redecorating a house or room with a new colour scheme. User might want to consider some of these suggestions about colours and how they might affect emotions and mood:

2.2.1. Psychological Effects of Cool Colours

Need to be creative? Want help getting those brain synapses firing? Try utilizing the colour purple. Purple utilizes both red and blue to provide a nice balance between stimulation and serenity that is supposed to encourage creativity. Light purple is said to result in a peaceful surrounding, thus relieving tension. These could be great colours for a home or business office.

Are the users looking for a peaceful and calming environment? Might consider using green and/or blue. These cool colours are typically considered restful. There is actually a bit of scientific logic applied to this – because the eye focuses the colour green directly on the retina, it is said to be less strainful on the eye muscles.

The colour blue is suggested for high-traffic rooms or rooms that user or other people will spend significant amounts of time. Another cool colour, blue is typically a calming and serene colour, said to decrease respiration and lower blood pressure. The bedroom is a great place to use these colours as they should help relax.

2.2.2. Psychological Effects of Warm Colours

Want to create an environment of stimulation or whet people's appetite? It might consider utilizing the colours yellow or orange. These colours are often associated with food and can cause the tummy to growl a little. Have ever wondered why so many restaurants use these colours? Now it's known why even after people watched the movie Supersize Me, they said they were hungry.

Users do want to be careful about using bright colours like orange and especially yellow. They reflect more-light and excessively stimulate a person's eyes which can lead to irritation. And also, probably don’t want to paint the dining room or kitchen these colours if user is a calorie-counter.

2.2.3. Psychology of Colour for Marketing & Advertising

Marketing and advertising are well-known for utilizing colour psychology. The fact that some companies have heavily invested in this type of research and many others have followed through in its use shows they have at enough belief in the concepts of colour psychology to implement them in their advertising.

Colour is consistently used in an attempt to make people hungry, associate a positive or negative tone, encourage trust, feelings of calmness or energy, and countless other ways.

Most marketing and advertising executives will likely agree that there are benefits to understanding and utilizing the psychological effects of colours. Now let’s take a look at some of the more common traits of colour psychology, by some common colours.

2.2.4. Colours and the emotions they evoke

Is it known that one of the lesser-known ways to invoke emotion [7] is through colour? It's well-known that poetry can make people swoon and a shocking image can enrage people into action, but the right use of colour can be equally as powerful. Only need to look at the world around to see, and feel, its impact.

Colours elicit unique responses in the viewer, and a savvy web designer (or any visual professional, actually) will be well versed in the effect of each individual colour, plus how and when to use each.

The discipline of colour theory may be broad (find out more about colour theory here), this thesis will teach the reader the

fundamentals in a single quick-reference source. However, before delving into the emotional nuances of 12 separate colours, it is needed to add a quick note about vibrancy. Want more? Explore these uses of colour in branding.
Simply put, a colour's vibrancy is how dark or light it is. The tricky part about vibrancy is that, just like each individual colour has its own properties, so does each shade of the same colour.

While light green and dark green have more in common than green and purple, they will still have smaller, more subtly different effects on the user.

Below, we'll explain all the noteworthy differences between a colour's shades, and consider their impact on web design. As a general rule, though, brighter shades tend to be more energetic, while darker shades feel more relaxing. The brighter shades of calls-to-action attract the eye, while the darker shades in backgrounds help create an immersive effect.

Now on to the impact of different colours on viewers...

RED

Passionate, aggressive, important
As a dominating colour, red adds gravity and heightened awareness – quite literally, as the colour increases blood circulation, breathing rates, and metabolism.

Red can take on a variety of meanings, associated with both love and war, but the unifying factor in all meanings is a sense of importance. Think of the red carpet.

Red is a colour best used cautiously. Its knack for attracting attention makes it a priceless tool for designers, but used excessively it will inhibit relaxation. Lighter shades emphasise the energetic aspects of red – including youthfulness – while darker shades emphasise power, and even durability, such as a brick wall.

ORANGE

Playful, energetic, cheap
Sharing red's energising aspects, but to a safer degree, orange is a good way to add excitement to a site without severity. It is generally playful, and some claim it creates haste and plays on impulse. It can even signify health, suggesting vitality and vibrance.

YELLOW

Happy, friendly, warning
Yellow is a strange colour: it is often associated with happiness, but also activates the anxiety centre of the brain. Like red and orange, it's able to stimulate and revitalise – it's the colour of warning signs and taxis – but use bright yellow sparingly because of the potential negative connotations.

Lighter shades play on the happiness aspects, reminding users of summer and the sun. Darker shades, including gold, add more weight and give a sense of antiquity.

The bright yellow-dominated colour palette on the post-it_(opens in new tab) website is synonymous with the product itself. It creates an energetic vibe, and is instantly recognisable as that particular brand.

GREEN

Natural, stable, prosperous
Green mostly represents the environment and outdoors, for obvious reasons, making it the clear choice to suggest nature and an organic quality.

As the bridge between stimulating, warm colours (red, orange, yellow) and calming, cool colours (blue, purple), green is the most balanced of colours, lending it an air of stability. It's also a popular choice as an accent or for calls-to-action because it stands out, but more softly than the warmer colours. In Western culture, it also represents money and financial safety.

BLUE

Serene, trustworthy, inviting

Blue is one of the most popular colours in web design – and for good reason. Seen blue on a lot of websites because, to put it simply, it is the colour of trust. Blue is the colour of calm and serenity, and as such inspires security and a feeling of safety.

For this reason, blue is a colour often used by banks: Citibank, Chase, Capital One and Barclays, for example, all use blue. However, the calming effects also make blue a friendly and inviting colour, which explains its adoption by Facebook and Twitter.

As if that weren't reason enough to use it, blue is also incredibly versatile; its vibrancy has more drastic effects than other colours. Light blue is the colour of water and the sky, so it generally has a refreshing and free feeling – and can be even energising if bright enough, while still retaining that reliable calm.

Darker blues tend to be more sombre, heightening the security aspects, which makes them an excellent choice for professionalism. Trust is essential for financial advisors such as Evolve Wealth (opens in new tab), so most of its site is designed in varying hues of blue.

All this comes at a small price, though: blue shouldn't be used for food-related sites. Because blue foods aren't common in the wild, studies show that the colour actually acts as an appetite suppressant.

PURPLE

Luxurious, mysterious, romantic
Long associated with royalty, purple creates an air of luxury, even decadence. Using a purple dominantly is a quick way to create a sense of elegance or high-end appeal, even if the product is budget-minded (an 'expensive' effect that's quite the opposite of orange).

Lighter shades of purple – especially lavender – bring to mind spring and romance. Darker shades add more mystery, and can even symbolise creativity. Darkening the shade will also turn the romantic elements more sensual.

With its ties to personal wealth, WooCommerce_(opens in new tab) chose purple as the colour to represent its Woo View app, playing on themes like royalty and panache that fit the function of checking how much money making in real time.

PINK

Feminine, young, innocent
Pink is a specialist colour that won't work for a lot of websites, but will work perfectly with the right audience. Because most people interpret pink as feminine, the colour is popular for targeting female users. However, don't overdo the pink-femininity connection, or else user is walking a fine line between appealing to users and pandering to gender stereotypes.

Its links with childhood and with sugary treats give pink a sweet, sometimes innocent appeal (not surprisingly a self-perpetuating cycle). It is also traditionally used with love and romantic themes, alongside red and light purple.

Rental service Rentberry_(opens in new tab)'s website uses pink as its key colour. In this case, it creates a soft, safe vibe, and intentionally distances itself from more corporate, traditional rental services.

BROWN

Earthy, sturdy, rustic

While not a popular choice in web design, brown can, under the right circumstances, be effective nonetheless. As the colour associated with the earth and trees, brown can add an outdoorsy feel, maximised by a pairing with green. The tree connotations also give a sturdy and reliable feeling.

In web design, brown is often used in conjunction with wood texturing, giving the same old-fashioned and rustic atmosphere of a wooden cabin.

While tech websites are typically dominated by stronger, bolder shades, the microsite for B&O Play used brown to great effect. The muted tones suggest a classier, more human side to the technology on offer. Natural connotations also remain: wood and leather feature prominently in the hero video, while a marble effect is used in the background.

BLACK

Powerful, sophisticated, edgy

As the strongest of all colours, black is often used only sparingly – such as for text – but it works quite well as a primary colour element (like for backgrounds). Much like purple, black adds an air of sophistication and elegance, and also mystery, though with much bolder confidence.

The heavy use of black for the Cartelle opens in new tab) creative agency creates unquestionable impact on its homepage and subsequent animations.

WHITE

Clean, virtuous, healthy

Literally the opposite of black, white pairs well with just about anything, making it ideal as a secondary colour. In a supporting role, white draws out the elements of more stimulating colours, and can even guide user's attention if user know how to use it (check out UXPin's Zen of White Space in Web UI Design(opens in new tab) guide to learn more).

As a primary colour, though, white gives off an impression that is both clean and chaste. White has that 'spotless' feeling that, for the right site, feels completely effortless. Its association with purity can make it seem virtuous, but also sterile and cold.

To soften this feeling of sterility, some web designers will tend towards an ivory or cream instead. These offshoots of white are softer and even less noticeable, but with the same minimalist and complementary aspects. They are the more comforting and less stark alternatives to white.

The shoe company ETQ_(opens in new tab) uses a dominant off-white background to keep the users' attention where it belongs: on the shoes.

GREY

Neutral, formal, gloomy

As the intermediary between black and white, grey exudes neutrality, or a lack of any particular sensation. However, in the hands of an expert, this intermediary position can be a powerful tool.

By varying the vibrancy, grey can take on the properties of either black or white – attention grabbing or repelling – to specific degrees. That means if black is too powerful for the design, try dark grey. If white is too bland, try light grey.

On its own, though, grey is rich with individual characteristics. It is the colour of formality, so sites aiming to look traditional or professional tend to favour it. It can also give a depressing vibe, as it's the colour of gloomy, rainy days. When used dominantly, it can be somewhat subduing, for better or worse.

It can be told to the Italian furniture company Galvan Mobili (opens in new tab) uses grey well because user don't even notice it. The grey background gives a professional air, and keeps attention on the pictures and bright red logo.

BEIGE

Accentuates surrounding colours
Beige may not be a primary colour, but it's worth mentioning because of its accentuating effects: it takes on the characteristics of the colours around it. While dull on its own, its enhancing effects make it a powerful choice as a background or secondary colour.

The use of beige for the aptly named Tokyo restaurant Beige Alain Ducasse_(opens in new tab) creates a calming, comfortable backdrop to the more relevant elements such as clickable text and photos.

2.3. Concept of Hue Lights

In colour theory, **hue** is one of the main properties (called colour appearance parameters) of a colour, defined technically in the CIECAM02 model as "the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, orange, yellow, green, blue, violet," which certain theories of colour vision call unique hues.

Hue can typically be represented quantitatively by a single number, often corresponding to an angular position around a central or neutral point or axis on a colour space coordinate diagram (such as a chromaticity diagram) or colour wheel, or by its dominant wavelength or by that of its complementary colour. The other colour appearance parameters are colourfulness, saturation (also known as intensity or chroma),[2] lightness, and brightness. Usually, colours with the same hue are distinguished with adjectives referring to their lightness or colourfulness - for example: "light blue", "pastel blue", "vivid blue", "cobalt blue". Exceptions include brown, which is a dark orange.

Hue [8] is more specifically described by the dominant wavelength and is the first item that makers refer to (i.e., “yellow”) when adding in the three components of a colour. Hue is also a term which describes a dimension of colour humans readily experience when they look at colour, or its purest form; it essentially refers to a colour having full saturation, as follows:

When discussing “pigment primaries” (CMY), no white, black, or grey is added when 100% pure. (Full desaturation is equivalent to a muddy dark grey, as true black is not usually possible in the CMY combination.)

When discussing spectral “light primaries” (RGB), a pure hue equivalent to full saturation is determined by the ratio of the dominant wavelength to other wavelengths in the colour.

Saturation defines the brilliance and intensity of a colour. When a *pigment* hue is “toned,” both white and black (grey) are added to the colour to reduce the colour’s saturation. In terms of the “additive” *light* colour model, though, saturation works on a scale based on how much or how little other hues are represented in the colour

2.3.1. Understanding Hue

Regardless of the two Additive and Subtractive colour models, all colour is a result of how our eyes physically process light waves. So, let’s start with the light Additive model to see how it filters into the Subtractive model and to see how hues, values and saturation interact to produce unique colours.

The three primary hues in light are red, green, and blue. Thus, that is why televisions, computer monitors, and other full-range, electronic colour visual displays use a triad of red, green, and blue phosphors to produce all electronically communicated colour.

As mentioned before, in light, all three of these wavelengths added together at full strength produces pure white light. The absence of all three of these colours produces complete darkness, or black.

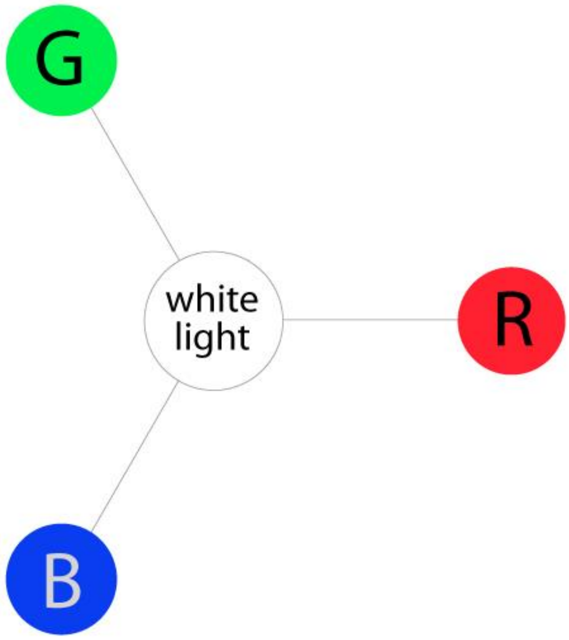

Fig. 2
RGB Primary Colour Triad

Mixing Adjacent Primaries = Secondary Hues

Making Cyan, Magenta, and Yellow:

Although additive and subtractive colour models are considered their own unique entities for screen vs. print purposes, the hues CMY do not exist in a vacuum. They are produced as secondary colours when RGB light hues are mixed, as follows:

1. Blue + Red light –> Magenta
2. Red + Green light –> Yellow
3. Green + Blue light –> Cyan

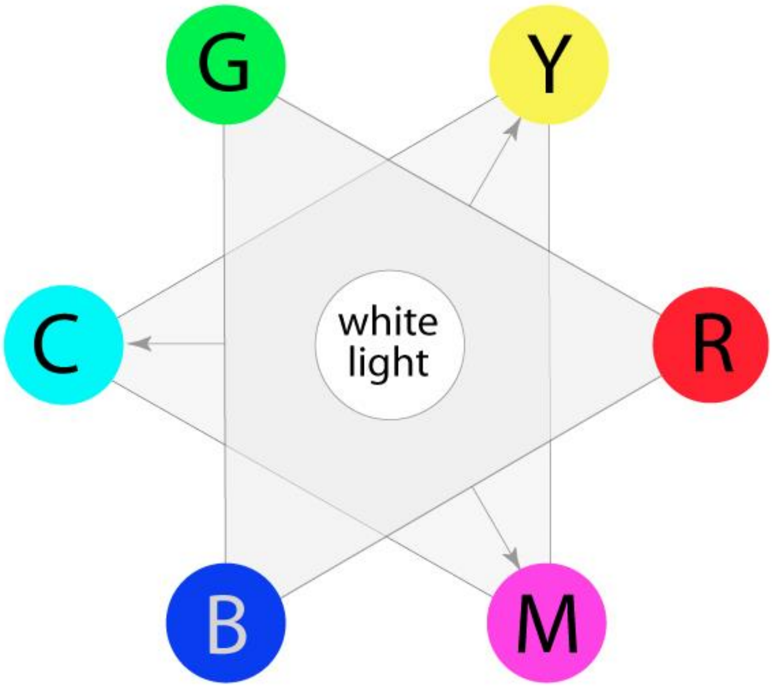

Fig. 3

CMY Secondary Light Colours

2.3.2. Overview of Hues

The colours on the outermost perimeter of the colour circle are the "hues," which are colours in their purest form. This process can continue filling in colours around the wheel. The next level colours, the tertiary colours, are those colours between the secondary and primary colours.

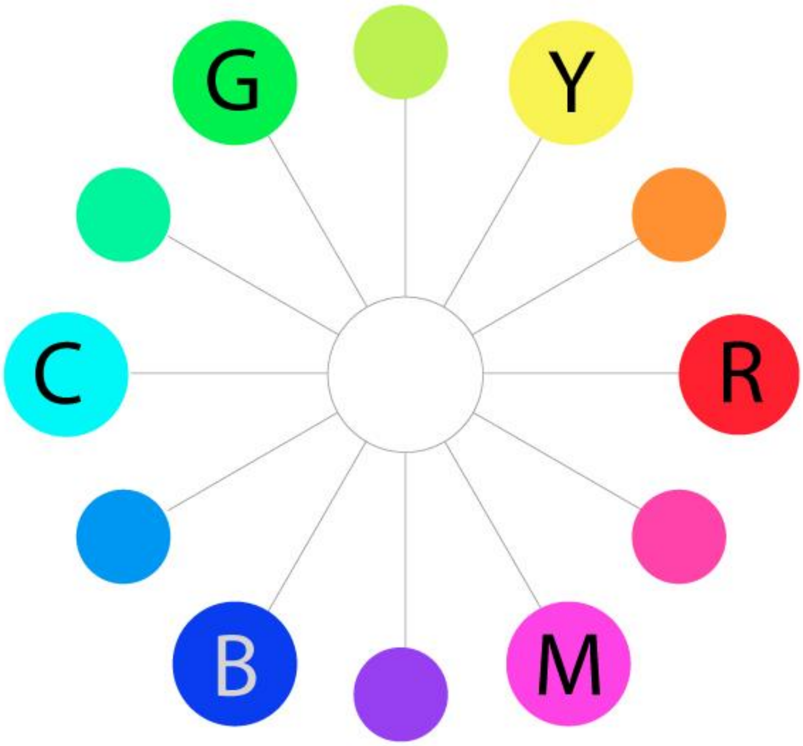

Fig. 4
Primary, Secondary, and Tertiary Hues

2.3.3. Saturation

Saturation is also referred to as “intensity” and “chroma.” It refers to the dominance of hue in the colour. On the outer edge of the hue wheel are the ‘pure’ hues. As and when a person moves into the centre of the wheel, the hue which have been used to describe the colour dominates less and less. When reach the centre of the wheel, no hue dominates. These colours directly on the central axis are considered **desaturated**.

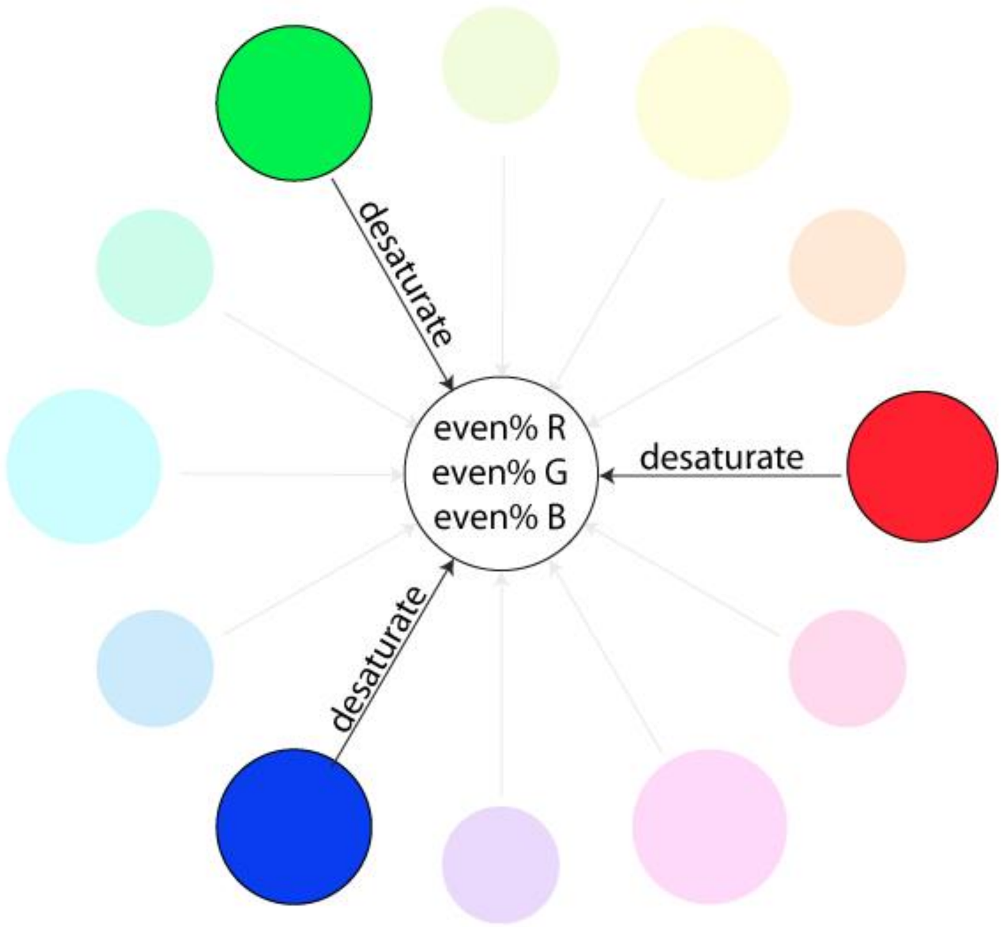

Fig. 5

Desaturation: hue becomes less dominant, moves to circle’s centre

Naturally, the opposite of the image above is to saturate colour. The first example below describes the general direction colour must move on the colour circle to become more saturated (towards the outside). The second example depicts how a single colour looks completely saturated, having no other hues present in the colour.

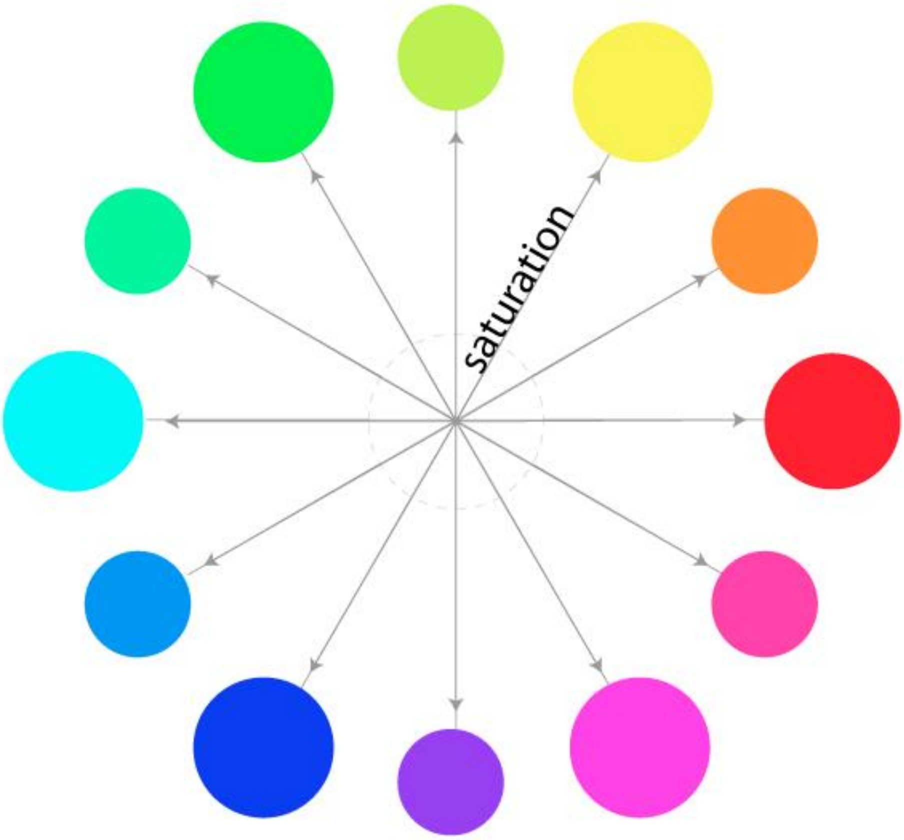

Fig. 6
General Saturation Direction

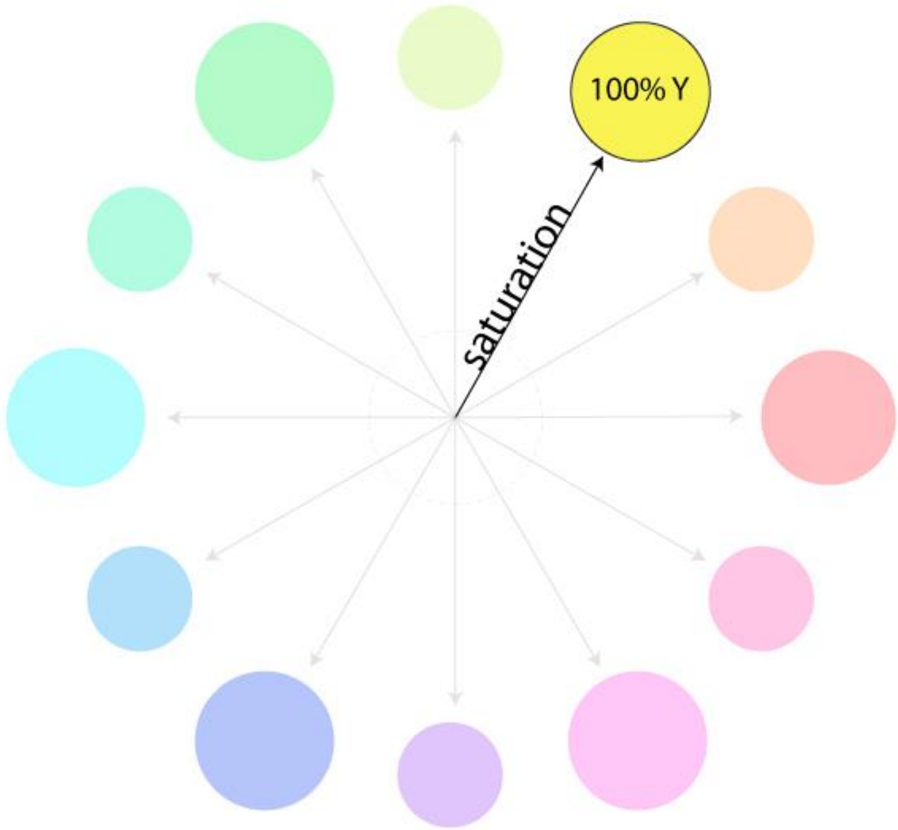

Fig. 7
"Pure" Hue with Complete Saturation: no other hues present

2.3.4. Value

Now let's add "value" to the HSV scale. Value is the dimension of lightness/darkness. In terms of a spectral definition of colour, value describes the overall intensity or strength of the light. If Hue can be thought of as a dimension going around a wheel, then value is a linear axis running through the middle of the wheel, as seen below:

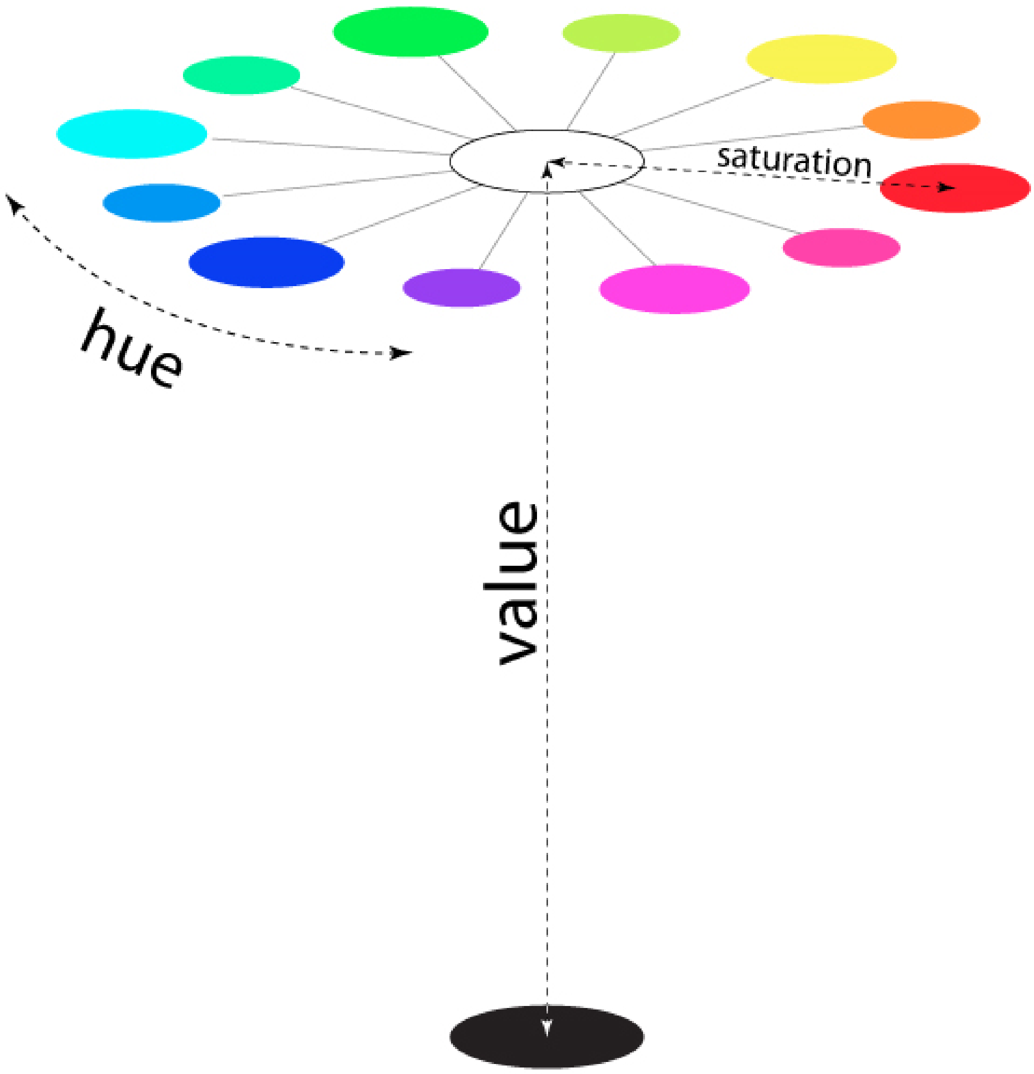

Fig. 8
HSV Model with Hue, Saturation, and Value Explained

To better visualize even more, the example below showing a full colour range for a single hue:

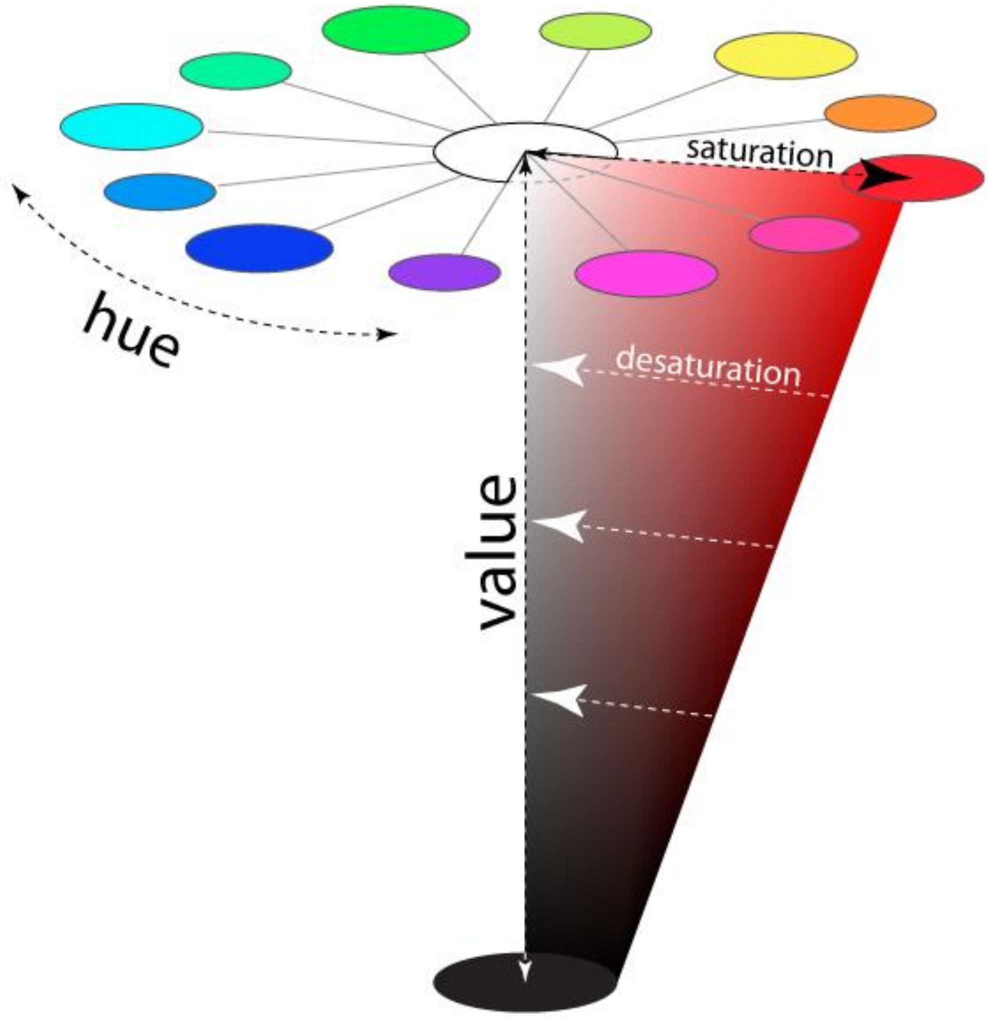

Fig. 9
HSV Model with Full Range of Single Hue

Now, if imagine that each hue was also represented as a slice like the one above, there would have a solid, upside-down cone of colours. The example above can be considered a slice of the cone. Notice how the right-most edge of this cone slice shows the greatest amount of the dominant red hue (least amount of other competing hues), and how as go down vertically, it gets darker in "value." Also notice that when travelling from right to left in the cone, the hue becomes less dominant and eventually becomes completely desaturated along the vertical centre of the cone. This vertical centre axis of complete desaturation is referred to as **grayscale**. See how this slice below translates into some isolated colour swatches:

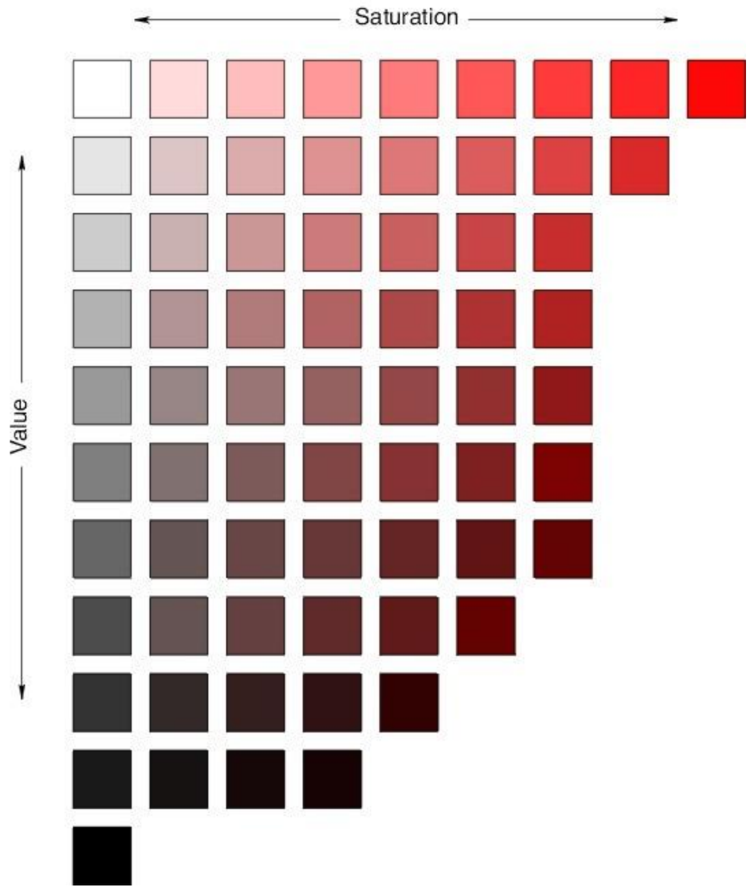

Fig. 10
Cone Slice Swatches

2.3.5. The HSV colour scale

The HSV scale clearly stands for "Hue, Saturation, Value." It does a better job at visually explaining the concept of light, and it is a very useful one to comprehend, as it is what most sophisticated digital colour pickers are based on (including all Adobe software). Not only do graphic designers need to understand this colour construct, but fine artists do as well since digital art and rendering has become such an integral part of art processes.

2.3.6. Colour Picker

With this explanation, it might be much easier to then understand how modern colour pickers work. There are many types of colour pickers, but this example will focus on the common Adobe software interface picker, continuing to use the red hue as the example below. By the way, relate the similarity of our cone-shaped red slice above to the “Select Colour” window below to better visualize how this works.

In Fig. 11 below, first notice the centre vertical slider. This is where the hue is been selected. It is currently set to the lowest selection and corresponds to the “H:0” radio button value on the right. The “H” indicates “Hue,” and the zero value describes which numerical hue assignment have been selected. Below it, it can be seen that “Red” is set to “255,” or the fullest level of light represented on a computer (0 = lowest). Notice that Blue and Green are set to zero, indicating that Red is at its fullest level of saturation.

Next, notice where the picker circle is in the “Select Colour” window. It is located at the top-right, indicating where on the scale user want the saturation to fall. As said, the sample is equivalent to the purest red hue with full saturation, and it corresponds to the outermost edge of the colour wheel. The “S:100%” on the right describes the level of saturation in the colour which have been selected, and the “B:100%” corresponds to the brightness, or value. As a side note, notice that under the CMYK levels that Yellow and Magenta are basically equally represented at their fullest capacities. This supports how in the Subtractive Colour Model; red is a secondary colour of yellow and magenta.

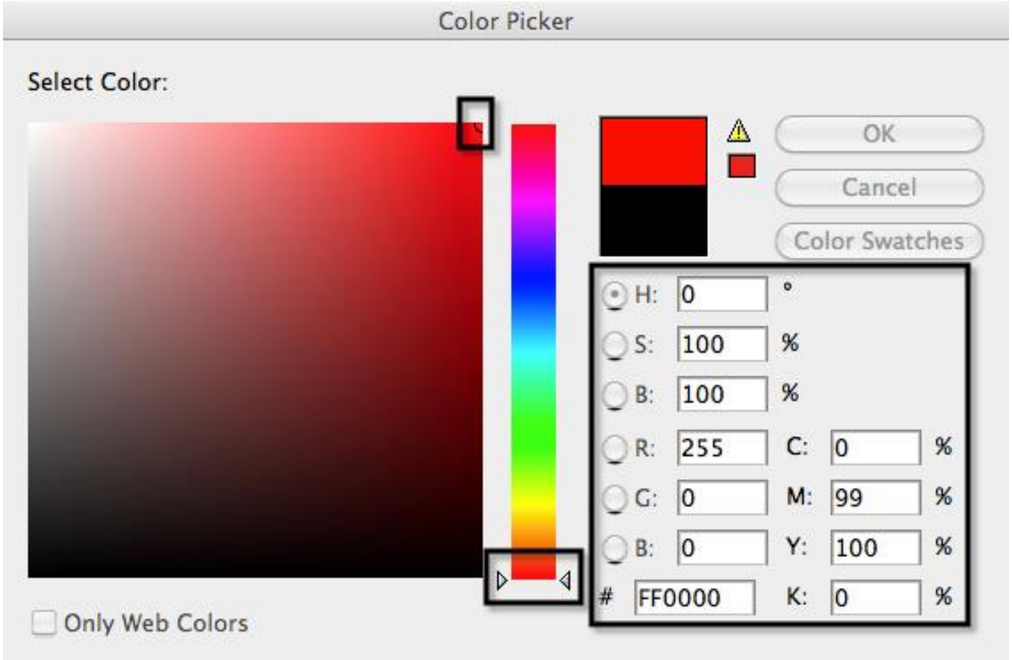

Fig. 11
RGB Colour Mode – Pure Red Hue

Now, as a means of comparison, look at the next model. Do see the difference?

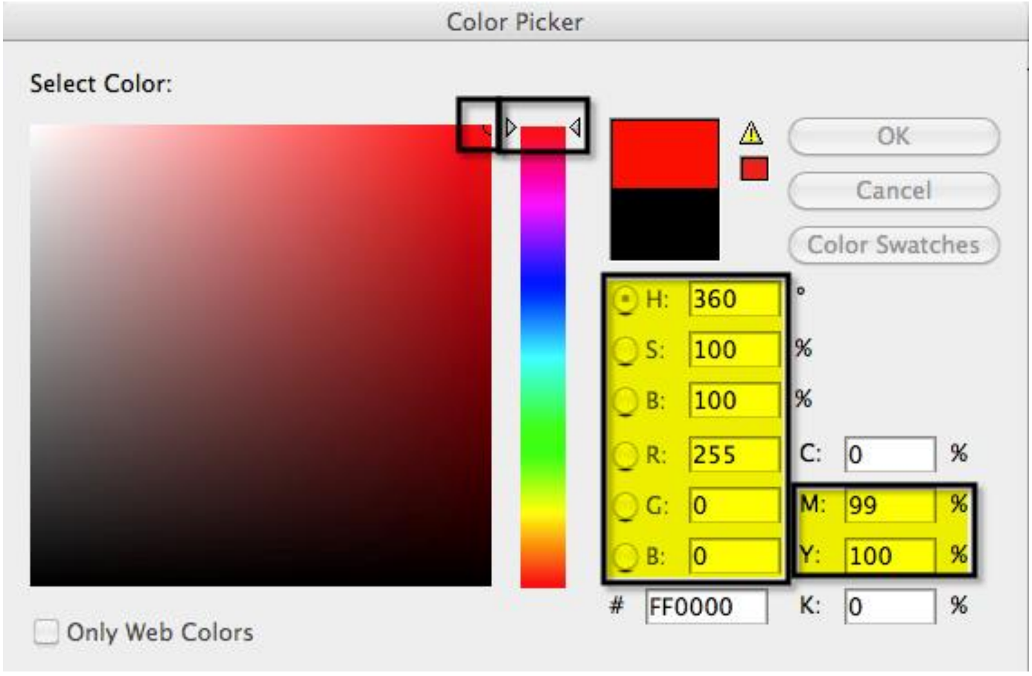

Fig. 12
RGB Colour Mode – Pure Red Hue

In case the difference is not visible, it is in the Hue number setting and where the slider is located. This is essentially the same hue as in the previous Fig. 11, except that the setting has gone from 0 to 360. This is because it has been based on the HSV cone model as illustrated earlier, and the hues at the top of the upside-down cone are in a full 360-degree circle. Thus, the circle has been completed by starting at the zero-level red and moving through the full visible spectrum to the same 360-level red.

To get a more complete picture of how this works, let's look at the RGB equivalent of "cyan", which is directly across from it on the colour wheel, and is thus red's complementary hue.

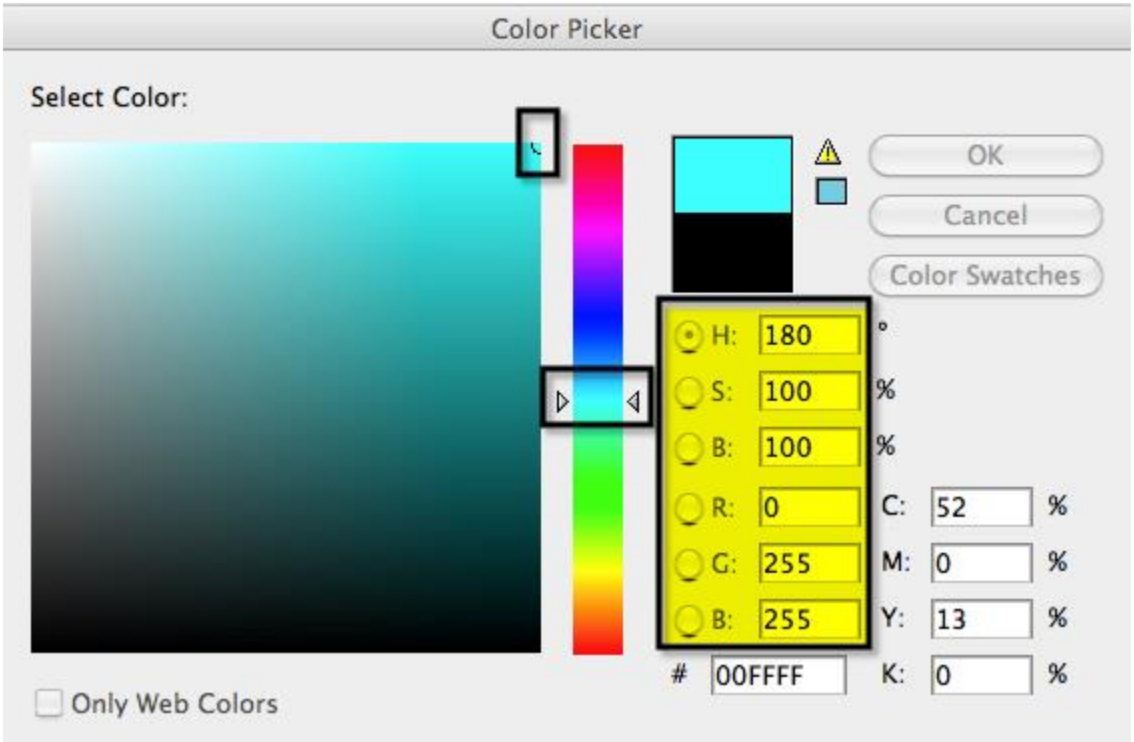

Fig. 13

RGB Models rendering of the secondary Cyan

Notice that in Fig. 13 that the hue setting is "180," or located at 180-degrees on the colour circle, half of 360. This is what numerically indicates the cyan is red's complement. Also, notice that it is the secondary RGB colour produced by mixing equal parts Blue and Green, where Blue=255, and Green=255. As a quick reminder of the basic colour wheel to help visualize, here is how cyan relates to red:

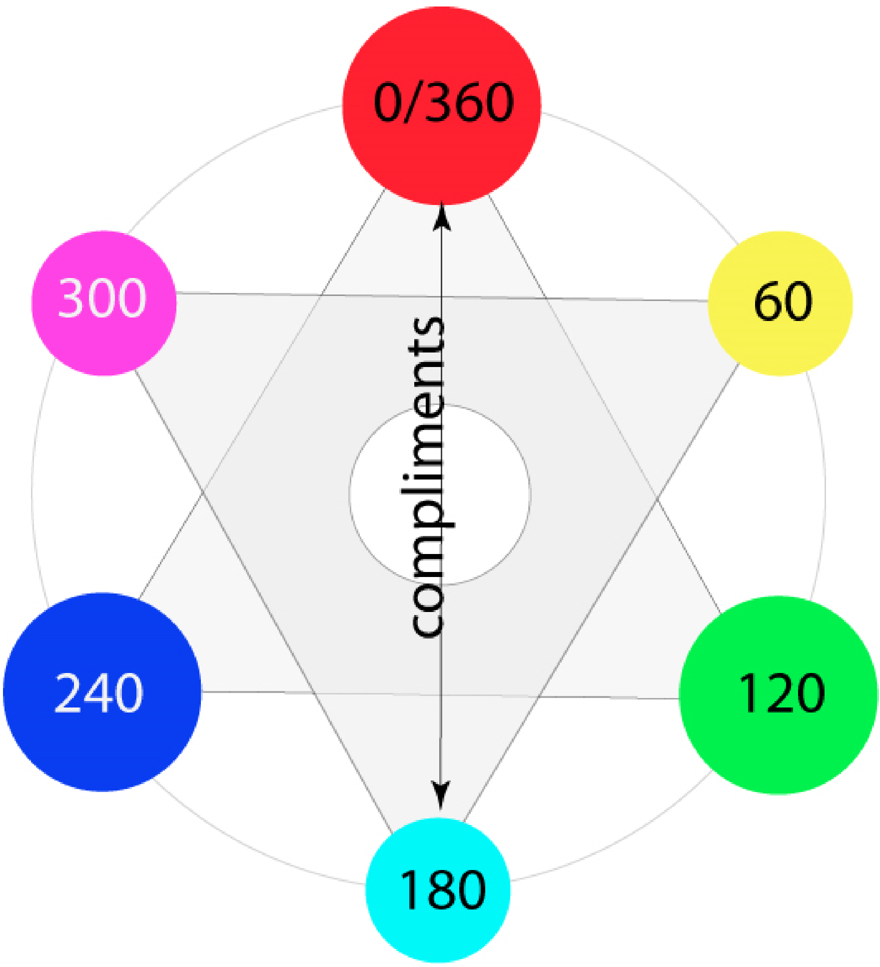

Fig. 14

HSV Degree of Hues to Illustrate Complements

CHAPTER 3

LIGHTING CONTROL METHODS

3. Lighting Control Methods

3.1. Introduction

A lighting control system is an intelligent network-based lighting control solution that incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices. Lighting control systems are widely used on both indoor and outdoor lighting of commercial, industrial, and residential spaces. Lighting control systems are sometimes referred to under the term smart lighting. Lighting control systems serve to provide the right amount of light where and when it is needed.

Lighting control systems are employed to maximize the energy savings from the lighting system, satisfy building codes, or comply with green building and energy conservation programs. Lighting control systems may include a lighting technology designed for energy efficiency, convenience and security. This may include high efficiency fixtures and automated controls that make adjustments based on conditions such as occupancy or daylight availability. Lighting is the deliberate application of light to achieve some aesthetic or practical effect (e.g., illumination of a security breach). It includes task lighting, accent lighting, and general lighting.

The term *lighting controls* [9] is typically used to indicate stand-alone control of the lighting within a space. This may include occupancy sensors, timeclocks, and photocells that are hard-wired to control fixed groups of lights independently. Adjustment occurs manually at each device's location. The efficiency of and market for residential lighting controls has been characterized by the Consortium for Energy Efficiency.

The term *lighting control system* refers to an intelligent networked system of devices related to lighting control. These devices may include relays, occupancy sensors, photocells, light control switches or touchscreens, and signals from other building systems (such as fire alarm or HVAC). Adjustment of the system occurs both at device locations and at central computer locations via software programs or other interface devices.

Today's advanced lighting controls provide the adaptability to plan lighting arrangements that are functional, energy-saving, and beautiful. In this article, we're going to look at some of the most common types of lighting controls that are out there and how they can help to conserve energy and create the ambiance that users are looking for in and around home.

3.2. What Can Lighting Controls Do?

There are a number of new technologies out there that make lighting controls that much more interesting, and they help to save a lot of energy and cash in the long run. One of the most innovative technologies is that of the motion sensor lights. These lights, as their names suggest, can sense when someone or something is coming in or out of a room so that user don't have to worry about "turning off the lights" when user leaves the room.

It used to be really pricey to get a lighting control system in home, and people assumed it was only for those who could afford something "lavish." As time has gone on, it's also become a lot more inexpensive to set up whole home with a lighting system. It couldn't be at a better time either, because as the prices of these technologies are decreasing, the cost of energy is increasing. So, while user may have to put a bit of upfront investment into the installation, the long-term costs end up being a lot lower for the users and their family.

3.3. Types of Lighting Controls

3.3.1. Basic Lighting Controls

It consists of a manual on/off switch. The occupants in the building must remember to turn them on when they enter the room and turn them off when they leave to save money with these types of lighting controls. Using energy-efficient light bulbs, like LEDs and CFLs, with basic switches, can help reduce electric bills.

3.3.2. Pre-set Lighting Controls

Pre-set lighting controls permit to change the brightness of the lighting by a little slider that is by the flip switch. The switch permits to turn the lights on and off, while the slider permits to modify the intensity of the light. There are pre-set dimmers that can be used as well, which implies that user can set them at a preferred setting that will stay at the pre-set level each time user turns the switch on. That being said, these dimmers can also help to save some energy when the user don’t really need a lot of light in a particular area of home.

3.3.3. Slide Lighting Controls

Slide lighting controls give full ranged, manual lighting control. Some are outfitted with a touch switch that permits the user to come back to the past lighting level when the lights are turned on. Others have a light on them that makes it easy to find them when the user come into the darkroom. They work the same way as the other dimmers, but instead of having pre-set lighting arrangements, user get to take control of exactly how much light want in the room that user is in.

3.3.4. Occupancy Sensors

Occupancy sensors automatically switch on indoor lights when they detect motion and switch them off when the area is not occupied for a specified amount of time. Occupancy sensors controls provide convenience by turning on the lights when someone enters the room and turn off the lights when the last person leaves the room resulting in 35-45 percent energy savings.

3.3.5. Motion Sensor Controls

Motion sensor controls are used for utility and security lighting. It turns on lights when it detects motion and turns it off a little later. Motion sensor controls are needed when lights need to be switched on when it is dark, and some people are present.

3.3.6. Dimmer Switches

Dimmer switches are a slightly more advanced technology to control room lighting. These switches allow an individual to slide the switch to their desired level of lighting that uses less electricity compared to a switch that is either fully on or fully off. When combined with LED light bulbs, dimmer switches can helps controlling building’s energy costs.

3.3.7. Touch Dimmers

Touch dimmers permits to change how intense the light is without using a switch to do so. User just touches the little touchpad, and the user can make the room lighter or darker. Touch lighting controls can also make it so that user can have light when leave a room, and then it will turn off after a certain number of minutes so that can save electricity and the user don’t have to worry about walking around in the dark. Dimmers increase the lifespan of bulbs and provide significant cost savings when lights are used at a low level.

3.3.8. Integrated Lighting Controls

They permits the user to make different pre-set lighting scenes inside a room. Scenes can be reviewed with the touch of a switch from a box or with handheld remote controls. A few makers have even begun offering these sorts of lighting controls that can control from a cell phone or another mobile device, which makes them that much more versatile and interesting to use, and it could end up saving a lot of time and money in the long run.

3.3.9. Networked Lighting Control Systems

This is the most advanced type of lighting control system, which can be part of a Building Automation System (BAS) package or designed as a stand-alone system. Networked lighting control systems allow the operators to control the lights from their computers or handheld devices that contain the lighting system software. Operators can turn lights on and off and set timers to control the lights. Advanced software programs can even store data and create usage charts so that energy usage can be precisely monitored.

These aren't the only types of lighting controls that are out there, but they're definitely the most common ones that a user will find on the market today. All of them have their advantages and disadvantages, and it will be found that the user can save a lot of money if user installs these lighting controls into the different areas of the home. A qualified professional can help the user decide which setups are best for the home arrangement and how user can save time and money by installing these incredibly handy devices.

3.4. Benefits of Using Lighting Controls

3.4.1. More energy efficiency

The golden rule for saving electricity is that the less time the lights are on, the lower will be the electricity bill. Lighting controls make it easy to know those're on only when need them.

People might forget to turn the lights off. With smart lighting, user can open the app and turn off lights even if the user is not in the house. Program a personal schedule on the timers and sensors or use vacancy sensors to trigger the lights to switch off when no one in the room. Also, whenever possible, dimers reduce the power to the lighting source, which will save energy, extend the bulb's life and reduce the need for electrical maintenance or repair from overuse.

Additionally, according to British Telecommunications, smart light bulbs can be at least 80 percent more efficient than typical bulbs.

3.4.2. Personal preferences

Lighting control systems offer intuitive flexibility. Change the amount of light depending on the time of day. Colour-changing smart light bulbs give user the creative freedom to set any kind of mood. Elevate user's mood with bright lighting or relax with dimmed ambiance as per user's choice. Think neon purple for dance parties, ambient yellow glow for movie night the favourite team's colour on game day. User can program whatever is necessary with a push of a button.

3.4.3. More convenience

The user can control the lighting system with ease on the devices the users are comfortable, including smartphones, tablets, laptops and desktop computers. Many systems also offer options of remotes or wall-mounted control centres to make it convenient to adjust in seconds.

Wireless switches don’t require complex cabling systems to install or maintain. Dimmers and energy-saving light controls make it easy to work from home in a well-lit, productive environment without wasting too much electricity.

3.4.4. Safety

The safety of the house means a lot as sensors can help navigate the house easily. To make the way to the bathroom in the night, a simple press of a button on the app can turn on the lights beforethe user even leaves their bed. User can also set the bedroom lights to mimic the rising and setting sun that the user wakes up and fall asleep naturally.

When user’s home, the exterior motion detectors turn on lights when someone walks by. This feature will alert the user to suspicious activity and deter intruders from targeting the user’s home. The U.S. Department of Energy recommended installing photosensors as they prevent outdoor lights from turning on during the daylight hours.

If the user is out of the station on vacation, setting the lights to turn on for a few hours each night can help deter anyone from taking advantage of user’s absence. While this feature will use up electricity, it will give the impression that someone is home.

3.5. Method used in this thesis work

As described earlier that there are different methods for a lighting control system. Model of this thesis work can obtain desired CCT, desired lux level for a particular CCT value as well as can set mood lighting condition as per users' choice. Therefore, the system used in this thesis work is a hybrid system, combining many different controlling techniques together to get the best possible result.

The CCT of light and lux level can be set using the touchpad of any smartphone. There are separate touchpad buttons for each mood of human beings which have been set as per the previous researches on mood lighting. The whole system is controlled through an IoT device 'nodeMCU ESP8266' Wi-Fi module.

CHAPTER 4

COMPONENTS, CIRCUIT, BLOCK DIAGRM & FLOW CHART

4. Components, Circuit, Block Diagram & Flow Chart

4.1. Components

4.1.1. Node MCU ESP8266 Wi-Fi module

In 2014, an ESP8266 Wi-Fi module was introduced and developed by third-party manufacturers like AI thinkers, which is mainly utilized for IoT-based embedded applications development. It is capable of handling various functions of the Wi-Fi network from another application processor. It is a SOC (System On-chip) integrated with a TCP/IP protocol stack, which can provide microcontroller access to any type of Wi-Fi network

What is the ESP8266 Wi-Fi Module?

An ESP8266 Wi-Fi module is a SOC microchip mainly used for the development of end-point IoT (Internet of things) applications. It is referred to as a standalone wireless transceiver, available at a very low price. It is used to enable the internet connection to various applications of embedded systems.

Espressif systems designed the ESP8266 Wi-Fi module to support both the TCP/IP capability and the microcontroller access to any Wi-Fi network. It provides the solutions to meet the requirements of industries of IoT such as cost, power, performance, and design.

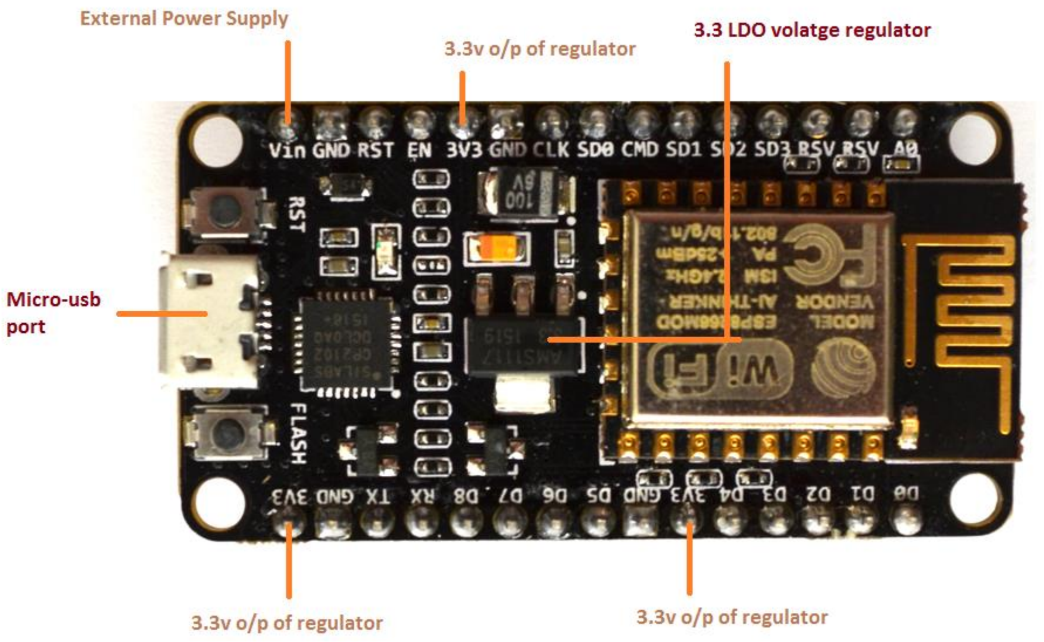

Fig. 15
ESP8266 Wi-Fi Module

It can work as either a slave or a standalone application. If the ESP8266 Wi-Fi runs as a slave to a microcontroller host, then it can be used as a Wi-Fi adaptor to any type of microcontroller using UART or SPI. If the module is used as a standalone application, then it provides the functions of the microcontroller and Wi-Fi network.

The ESP8266 Wi-Fi module is highly integrated with RF balun, power modules, RF transmitter and receiver, analogue transmitter and receiver, amplifiers, filters, digital baseband, power modules, external circuitry, and other necessary components. The ESP8266 Wi-Fi module is a microchip shown in the figure below.

A set of AT commands are needed by the microcontroller to communicate with the ESP8266 Wi-Fi module. Hence it is developed with AT commands software to allow the Arduino Wi-Fi functionalities, and also allows loading various software to design the own application on the memory and processor of the module.

The processor of this module is based on the Tensilica Xtensa Diamond Standard 106 micro and operates easily at 80 MHz. There are different types of ESP modules designed by third-party manufacturers.

They are -

ESP8266-01 designed with 8 pins (GPIO pins -2)

ESP8266-02 designed with 8 pins (GPIO pins -3)

ESP8266-03 designed with 14 pins (GPIO pins- 7)

ESP8266-04 designed with 14 pins (GPIO pins- 7)

The ESP8266 Wi-Fi module comes with a boot ROM of 64 KB, user data RAM of 80 KB, and instruction RAM of 32 KB. It can support 802.11 b/g/n Wi-Fi network at 2.4 GHz along with the features of I2C, SPI, I2C interfacing with DMA, and 10-bit ADC. Interfacing this module with the microcontroller can be done easily through a serial port. An external voltage converter is required only if the operating voltage exceeds 3.6 Volts. It is most widely used in robotics and IoT applications due to its low cost and compact size.

The ESP8266-01 Wi-Fi module runs in two modes -

Flash Mode: When GPIO-0 and GPIO-1 pins are active high, then the module runs the program, which is uploaded into it.

UART Mode: When the GPIO-0 is active low and GPIO-1 is active high, then the module works in programming mode with the help of either serial communication or Arduino board.

The ESP8266 Wi-Fi module pin configuration/pin diagram is shown in the figure below –

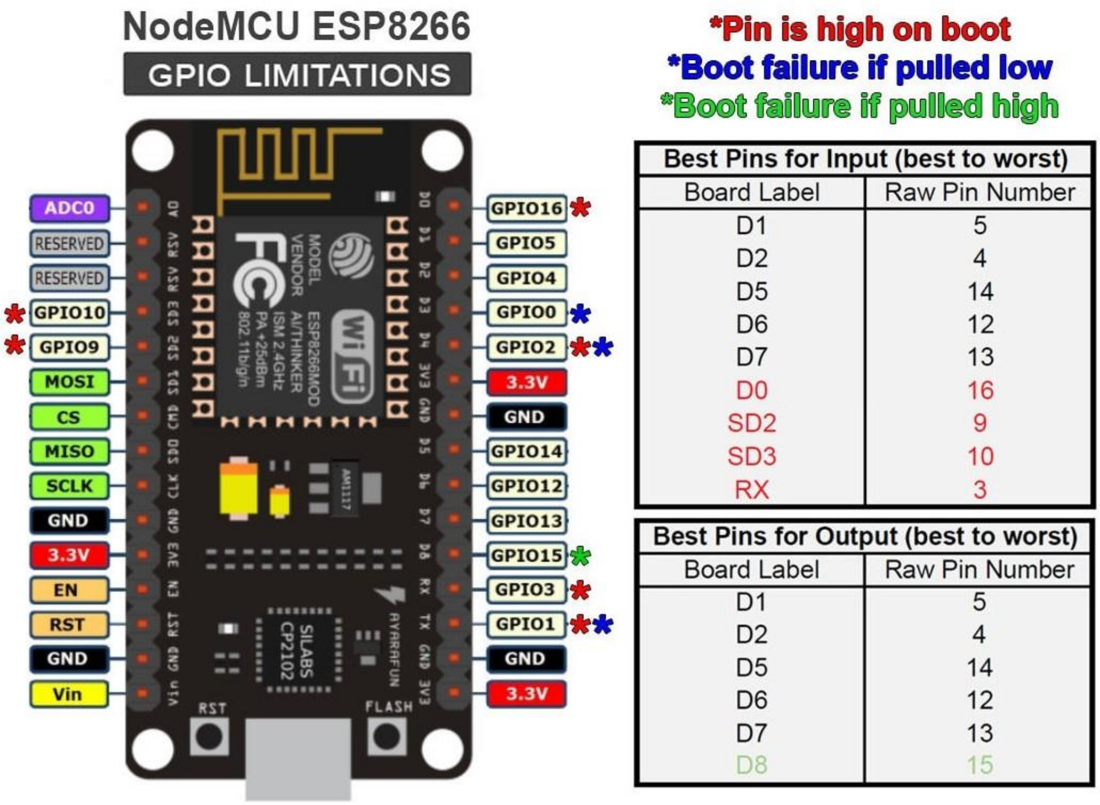

Fig. 16
Pin Configuration/Pin Diagram

ESP8266 Wi-Fi Module Specifications –

- The ESP8266 Wi-Fi module specifications or features are given below.
- It is a powerful Wi-Fi module available in a compact size at a very low price.

- It is based on the L106 RISC 32-bit microprocessor core and runs at 80 MHz
- It requires only 3.3 Volts power supply
- The current consumption is 100 m Amps
- The maximum Input/Output (I/O) voltage is 3.6 Volts.
- It consumes 100 mA current
- The maximum Input/Output source current is 12 mA
- The frequency of built-in low power 32-bit MCU is 80 MHz
- The size of flash memory is 513 kb
- It is used as either an access point or station or both
- It supports less than 10 microAmps deep sleep
- It supports serial communication to be compatible with several developmental platforms such as Arduino
- It is programmed using either AT commands, Arduino IDE, or Lua script
- It is a 2.4 GHz Wi-Fi module and supports WPA/WPA2, WEP authentication, and open networks.
- It uses two serial communication protocols like I2C (Inter-Integrated Circuit) and SPI (Serial Peripheral Interface).
- It provides 10- bit analogue to digital conversion
- The type of modulation is PWM (Pulse Width Modulation)
- UART is enabled on dedicated pins and for only transmission, it can be enabled on GPIO2.
- It is an IEEE 802.11 b/g/n Wi-Fi module with LNA, power amplifier, balun, integrated TR switch, and matching networks.
- GPIO pins – 17
- Memory Size of instruction RAM – 32 KB
- The memory size of instruction cache RAM – 32 KB
- Size of User-data RAM- 80 KB
- Size of ETS systems-data RAM – 16 KB

Circuit Diagram for working –

There are several techniques and IDEs are available by using ESP8266 Wi-Fi modules. The Arduino IDE is the most commonly used technique. Now, let’s learn the working of the Arduino IDE using the ESP8266 Wi-Fi module. The circuit diagram/how to use the Arduino IDE or FTDI device is illustrated in the below figure.

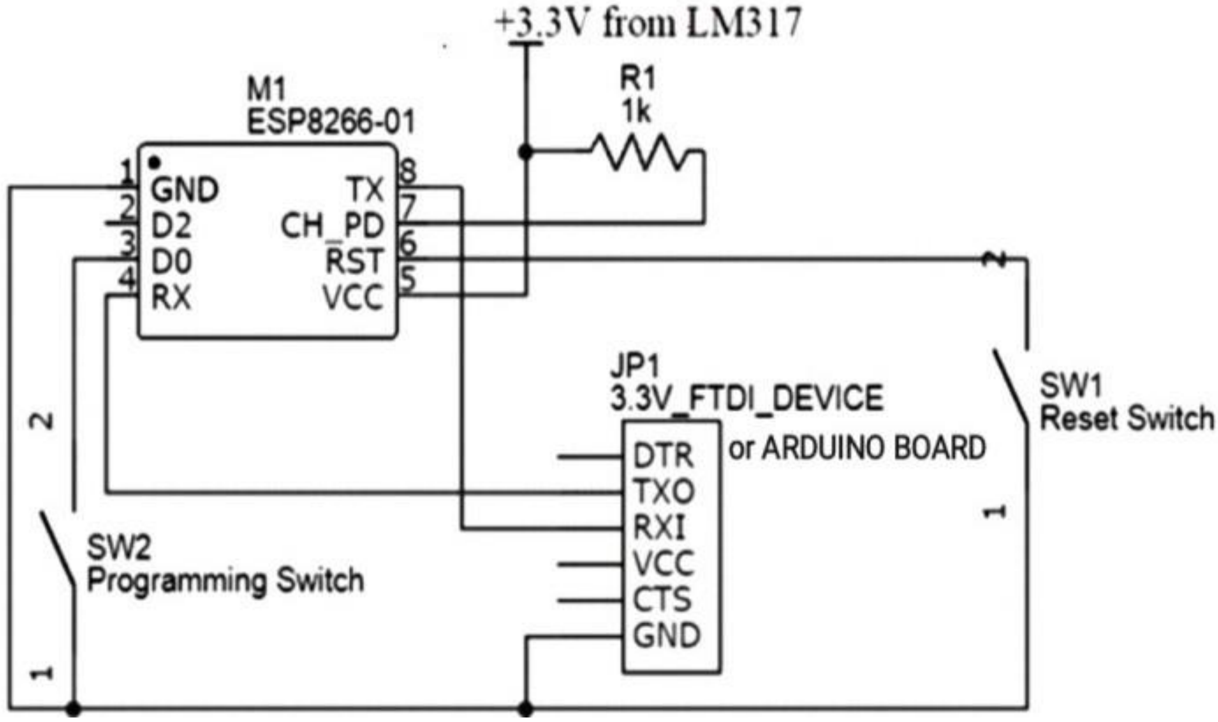

Fig. 17

Circuit Diagram describing how to use

The power supply required for the ESP8266 module is only 3.3 Volts. If it is more than 3.7 Volts, then the module gets damaged, and this leads to circuit failure.

Hence it is necessary to program the ESP-01 Wi-Fi module by using either Arduino board or FTDI device, which supports the programming 3.3 Volts supply. It is recommended for the user to buy either one FTDI device or an Arduino board.

The most common issue with the ESP-01 module is the powering up issue. The 3.3 Volts pin on the Arduino board is used to power up this module or simply a potential divider can used. So, to provide a minimum current of 500 mA, the voltage regulator that supports 3.3 Volts is mandatory. The LM317 voltage regulator does this work very easily and effectively.

The programming switch SW2 is pressed to connect the GPIO-0 pin to the GND (Ground). This is the programming mode to upload the code by the user. After uploading the code, the switch is released.

How Does It Work?

The ESP8266 can be controlled from the local Wi-Fi network or from the internet (after port forwarding). The ESP-01 module has GPIO pins that can be programmed to turn an LED or a relay ON/OFF through the internet. The module can be programmed using an Arduino/USB-to-TTL converter through the serial pins (RX, TX).

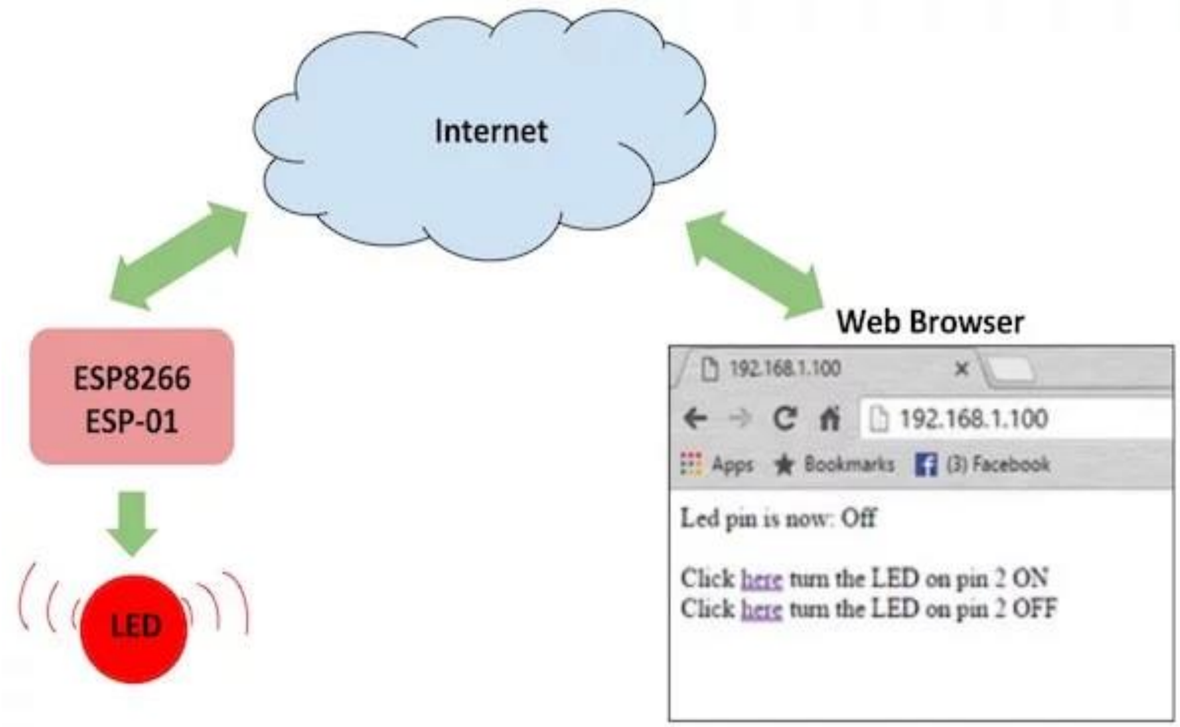

Fig. 18
Working with internet

4.1.2. RGB LED

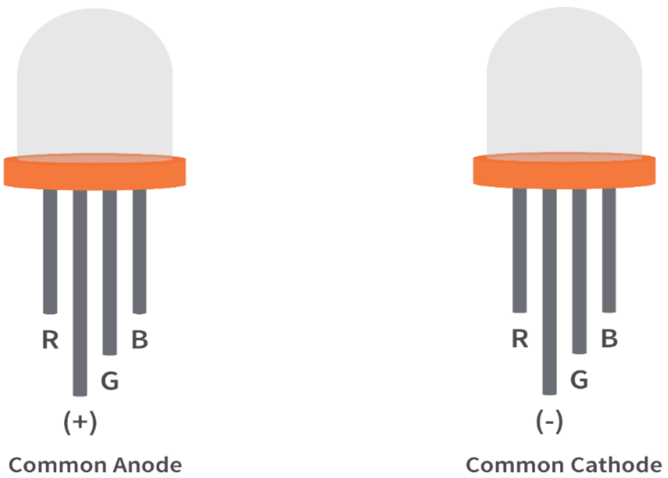

Fig. 19
4-legged common cathode and common RGB LEDs

What is an RGB LED?

The RGB LED is a type of LED that can produce three main colours that are RED, GREEN, and BLUE. In other words, it’s a single LED that contains three LEDs inside it. One for the RED colour, one for the GREEN colour, and one for the BLUE colour. The RGB LED that will be discussing in this article is non-programmable and it is of two types. One is a common anode RGB LED and the other is a common cathode RGB LED.

A common anode RGB LED consists of four terminals out of which one is for the common anode, one is for the RED LED cathode terminal, one is for the GREEN LED cathode terminal, and the last one is for the BLUE LED cathode terminal. It is called a common anode RGB LED because in this type of RGB LED, the anode terminal of all three LEDs is shorted internally and connected to one terminal and that terminal is known as a common anode terminal.

On the other hand, a common cathode RGB LED also consists of four terminals but in this type of RGB LED one terminal is for the common cathode, one is for the RED LED anode terminal, one is for the GREEN LED anode terminal and the last one is for the BLUE LED anode terminal. It is called a common cathode RGB LED because in this type of LED, the anode terminal of all three LEDs is shorted internally and connected to one terminal and that terminal is known as a common anode terminal.

Types of RGB LEDs -

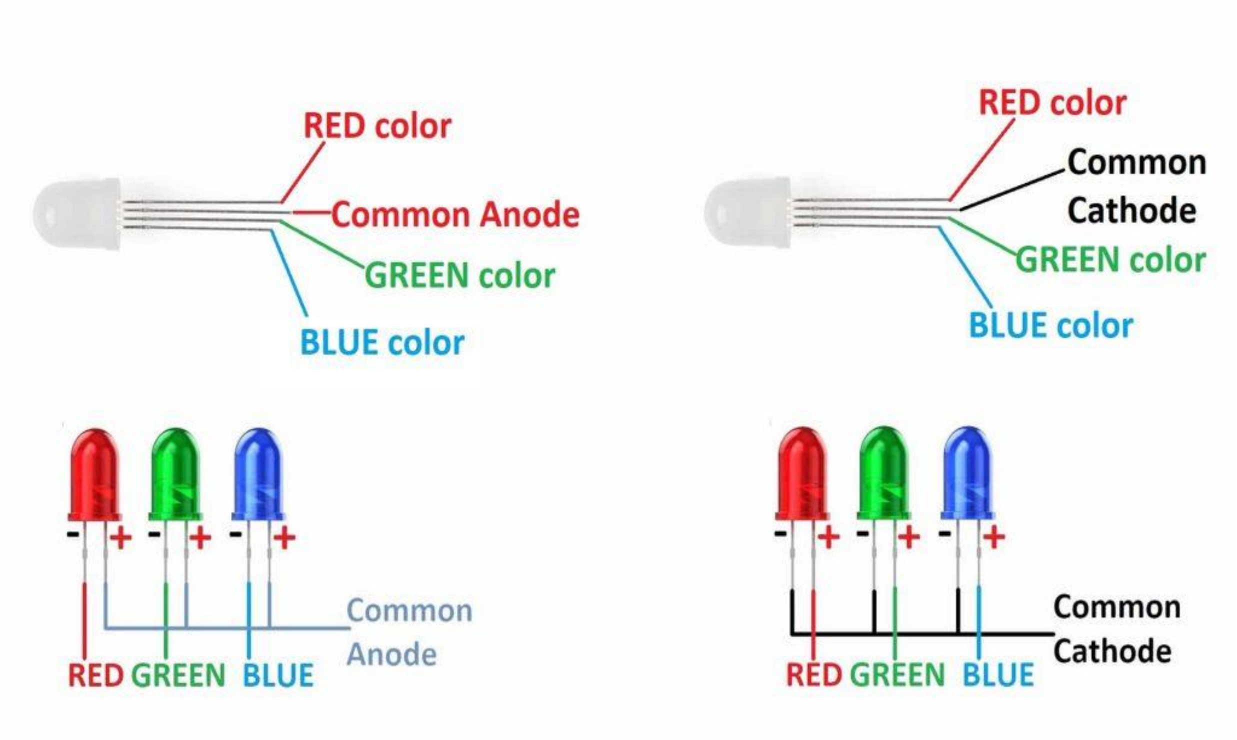

Fig. 20

RGB LEDs with leg markings

Specifications of RGB LED –

- Forward voltage: RED colour – 1.8 to 2.2 V, GREEN colour – 3.0 to 3.4 V, BLUE colour – 3.0 to 3.4 V
- Forward current: RED colour – 20mA, GREEN colour – 20mA, BLUE colour – 20mA
- Reverse current (at 5V): RED colour – 10uA, GREEN colour – 10uA, BLUE colour – 10uA
- Luminous Intensity: RED colour – 800mcd, GREEN colour – 4000mcd, BLUE colour – 900mcd
- Operating temperature: -25 to 85 degrees Celsius

Working of the RGB LED –

To light up a common anode RGB LED, user have to connect its common terminal to the positive terminal of the power source. Then to light up the RED colour, connect the RED colour terminal to the negative terminal of the power source. Do the same for the other colours.User can also light up two or all three colours simultaneously, then will get different colour combinations.

To light up a common cathode RGB LED, user have to connect its common terminal to the negative terminal of the power source. Then to light up the RED colour, connect the RED colour terminal to the positive terminal of the power source. It will also work in the same manner as that of the common anode RGB LED.

By directly applying a voltage to both the types of LED and can get the RED colour, BLUE colour, GREEN colour, a combination of RED and BLUE colour, a combination of RED and GREEN colour, a combination of BLUE and GREEN colour, and a combination of all the three colours. So, the user will get a total of 7 colours.

Operation: Analog to Digital Conversion and vice-versa

or the analogue voltages from 0 V to 5V, values (0 - 255) are entered as digital values.

It is done by adhering to the formula and relationship:

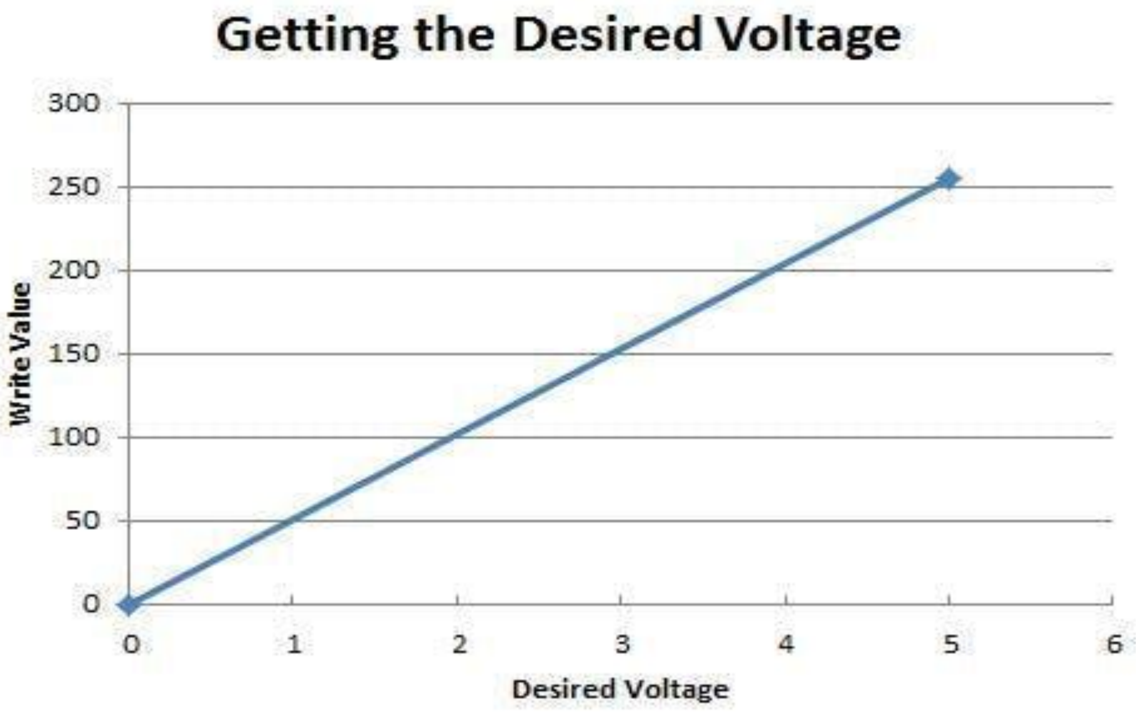

Fig. 21
Voltage vs HSL score graph

The formula can be evaluated using the equation of line with two points on graph.

Digital Value = 51 x Analog Voltage

For example, if analogue voltage of 2 V is required, then digital value to be entered is 2 times 51 which is equal to 102.

4.2. Circuit Diagram

The circuit is simple and easy to construct, the main hard work is in the research, gathering information, implementing the results, calculating the calibrated values and witing efficient coding.

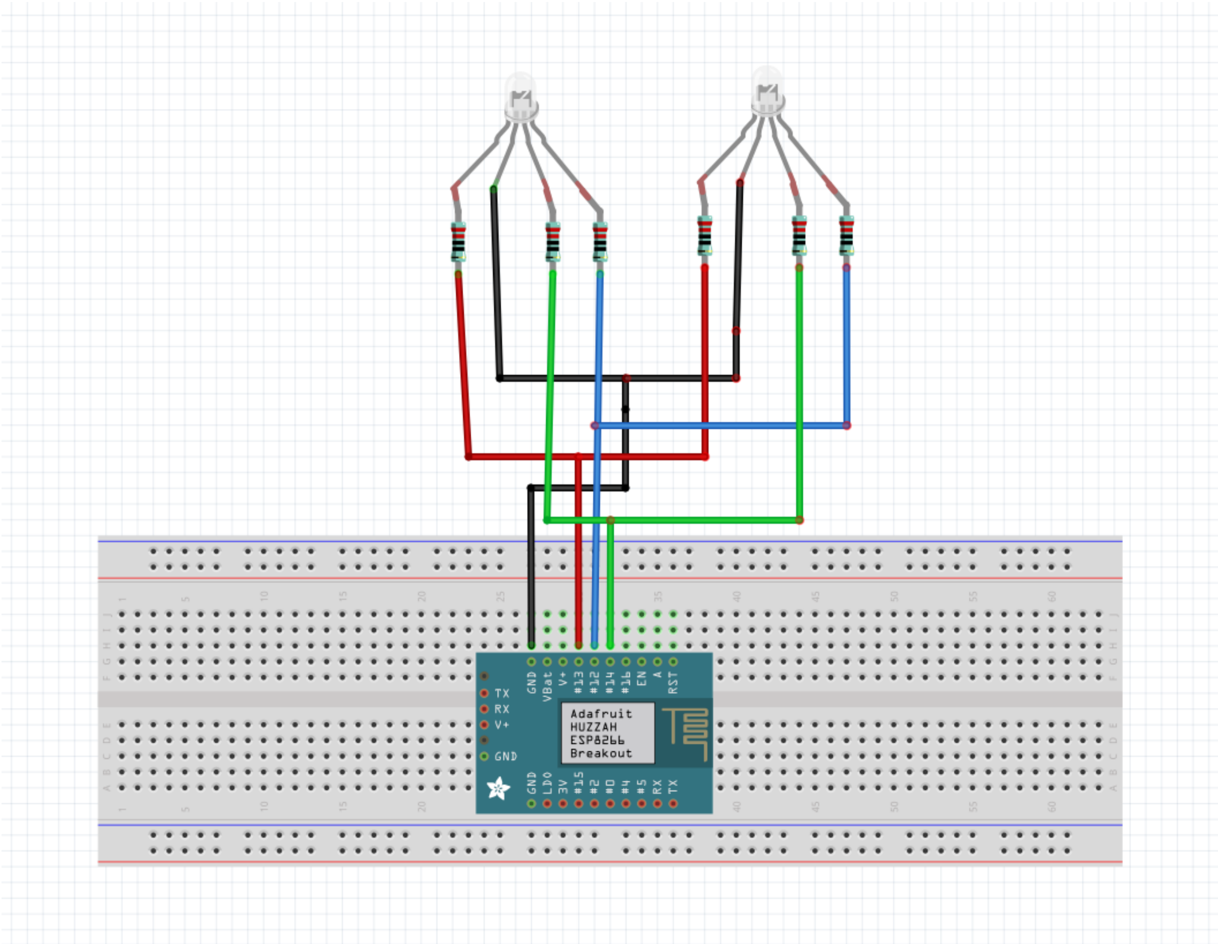

Fig. 22
Simulation Circuit Diagram

Here in the circuit, a four-legged common cathode (negative) RGB LED is been connected in series with three 10 kilo ohm resistor in the R, G and B leg each, and to the NodeMCU pin no. D0, D1 and D2. The nodeMCU is been powered directly from USB type 2 smartphone charger, taking 230V, 50/60Hz as input and giving 0-5V, 2A output.

4.3. Block Diagram

Block diagram actually helps to better understand what is really happening at the back side. Here the role of smartphone is been clearing described, which gives the control signal to set the desired lighting condition.

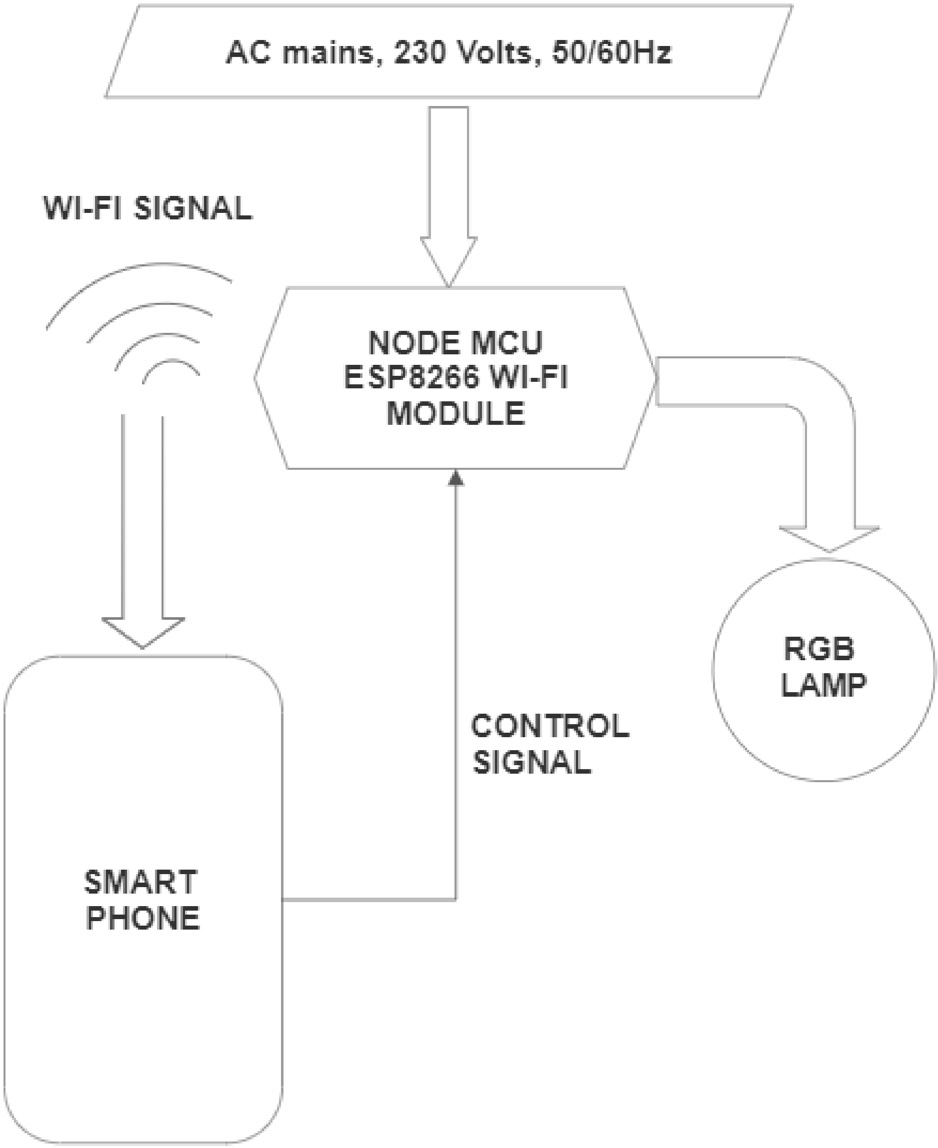

Fig. 23
Block Diagram

It starts from powering the Node MCU directly from the supply mains using a type-2 USB mobile charger. As soon as it is powered up, it acts as a Wi-Fi hotspot, providing a network named “Prashant RGB” with password set as “RGB007”.

After connecting to that hotspot network, it enables the user to open a webpage https://rgb without any internet connection. Using that webpage only user can change, adjust and set desired CCT and illuminance level.

This happens as shown in the block diagram. The control signal from the smartphone goes back to the node MCU as a command to change lighting condition on real-time, this command get converted to different calibrated inputs which is then provided to each leg of the RGB LED to set the HSL or RGB colour code values as variable voltage-constant current.

4.4. Flow Chart on how to operate

This flow chart helps to understand the process or say working in a single go i.e., flow. It initiates a proper understand of the whole process step by step which are sometimes become very difficult to understand.

Here the flow chart is for the operations need to perform in order to use to the model/device. It starts with powering the Node ESP8266 Wi-Fi Module. As soon as it is powered, a Wi-Fi hotspot is been created by the device, named “Prashant rgb”. The user needs to connect to this Wi-Fi network. After successful connection to this network, user need to open http://rgb in their web-browser.

A pixel screen appears having 16 million different colours to choose from. Just by sliding on the screen with finger or cursor will change the colour along with its intensity. Below the colour screen there are buttons for different moods.

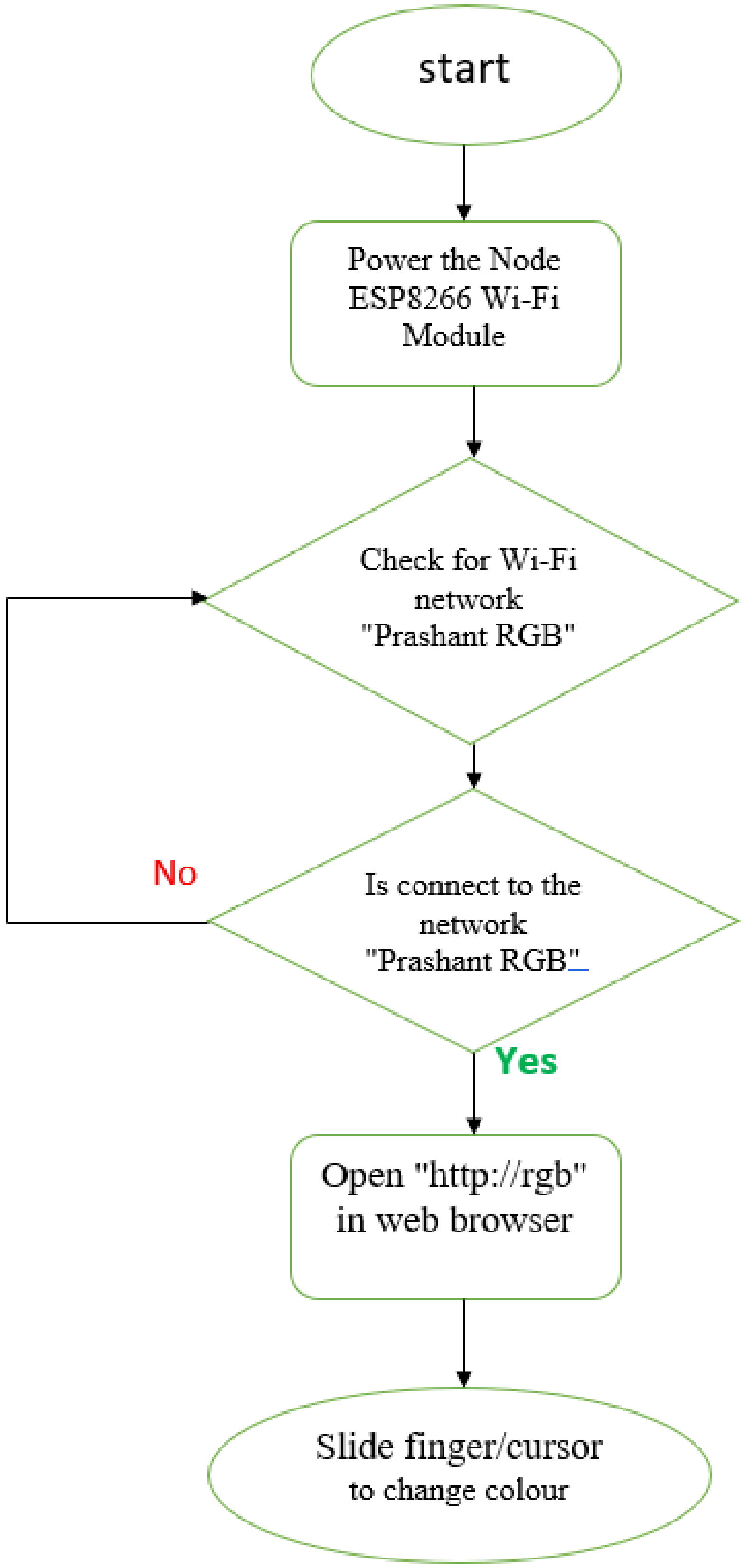

Fig. 24

Flow Chart on how to operate

4.5. Components Used

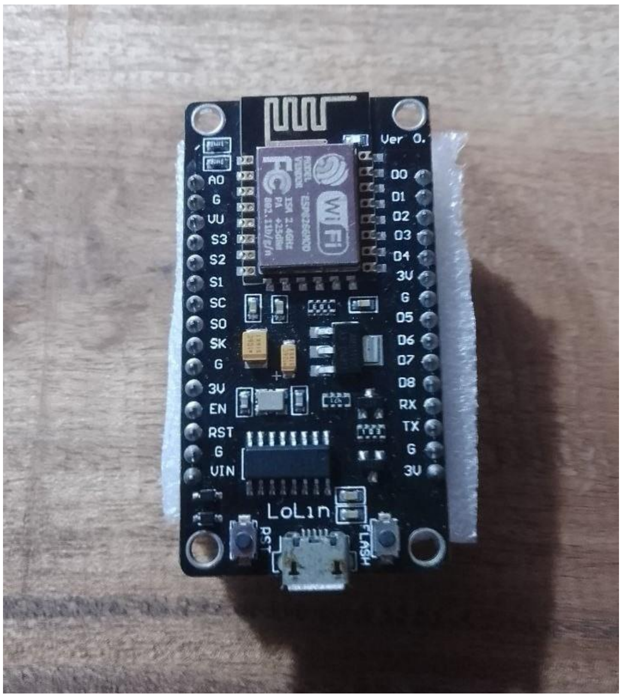

Fig. A
ESP8266 Wi-Fi Module

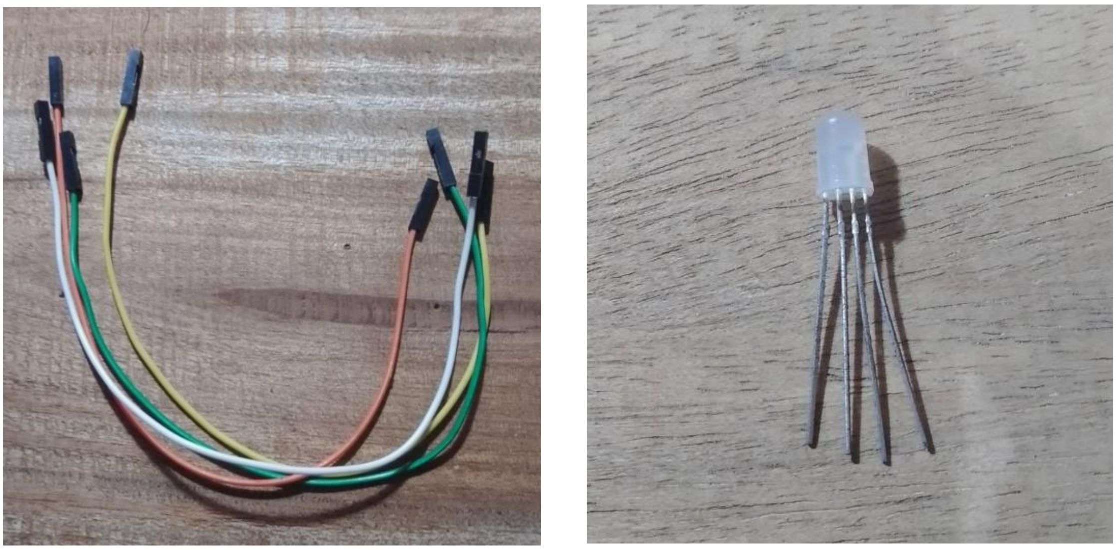

Fig. B
On left: Jumper wire, on right: RGB LED

CHAPTER 5

CIRCUIT DEVELOPMENT & WORKING

5. Circuit Development and Working

5.1. Circuit Development

It's very important to choose circuit design carefully, as not every device available in the market is suitable form the RGB LED control.

So, here a comparison with similar devices is been shown to identify which device suits perfectly for this circuit.

5.1.1. Arduino

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on user's computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – a USB cable can simply be used. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

The Uno is one of the more popular boards in the Arduino family and a great choice for beginners. We'll talk about what's on it and what it can do later in the tutorial.

The Arduino hardware and software was designed for artists, designers, hobbyists, hackers, newbies, and anyone interested in creating interactive objects or environments. Arduino can interact with buttons, LEDs, motors, speakers, GPS units, cameras, the internet, and even the smart-phone or the TV! This flexibility combined with the fact that the Arduino software is free, the hardware boards are pretty cheap, and both the software and hardware are easy to learn has led to a large community of users who have contributed code and released instructions for a huge variety of Arduino-based projects.

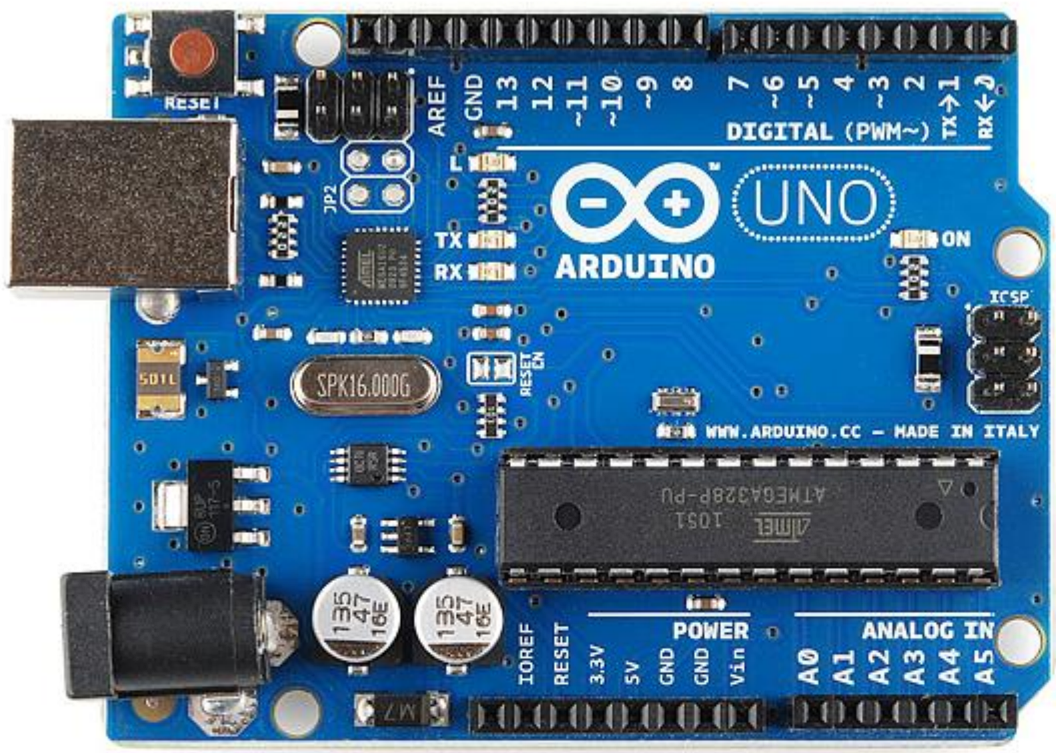

Fig. 25
Arduino Uno R3 board

For everything from robots and a heating pad hand warming blanket to honest fortune-telling machines, and even a Dungeons and Dragons dice-throwing gauntlet, the Arduino can be used as the brains behind almost any electronics project.

The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. The Diecimila, Duemilanove, and current Uno provide 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs, which can also be used as six digital I/O pins. These pins are on the top of the board, via female 0.1-inch (2.54 mm) headers. Several plug-in application shields are also commercially available. The Arduino Nano, and Arduino-compatible Bare Bones Board and Boarduino boards may provide male header pins on the underside of the board that can plug into solderless breadboards.

Many Arduino-compatible and Arduino-derived boards exist. Some are functionally equivalent to an Arduino and can be used interchangeably. Many enhance the basic Arduino by adding output drivers, often for use in school-level education, to simplify making buggies and small robots. Others are electrically equivalent, but change the form factor, sometimes retaining compatibility with shields, sometimes not. Some variants use different processors, of varying compatibility.

Drawbacks -

Arduino shields away a lot of complexity which is an advantage to get started, but limits expansion later. It also makes understanding how certain things work more difficult, but that's inevitable.

Users are limited to a small number of MCUs right now: Arduino is only officially supported on the Atmel AVR and Atmel SAM series. There are ports and adaptions to a few other MCUs like the

ESP8266 or even the nRF51 series, but they don't seem to be fully supported, so generally it’s been limited to Atmel MCUs.

The Arduino libraries are not very efficient in certain parts and waste RAM and CPU cycles (Example: http://bleaklow.com/2012/02/29/why_im_ditching_the_arduino_software_platform.html).

The Arduino IDE is very limited and a really bad code editor. That however can be fixed, user can use a different editor to write the code. It has been suggested to use PlatformIO as a build tool chain and any editor like (e.g., GitHub's Atom, which as great support for Arduino).

Conclusion –

The Arduino Uno R3 which is the most common version of Arduino is not suitable for Wi-Fi supported devices. It doesn’t allow wireless connectivity or controls, hence fails to make the cut for the minimum requirement.

5.1.2. Raspberry Pi

Raspberry Pi is the name of a series of single-board computers made by the Raspberry Pi Foundation, a UK charity that aims to educate people in computing and create easier access to computing education.

The Raspberry Pi launched in 2012, and there have been several iterations and variations released since then. The original Pi had a single-core 700MHz CPU and just 256MB RAM, and the latest model has a quad-core CPU clocking in at over 1.5GHz, and 4GB RAM. The price point for Raspberry Pi has always been under

$100 (usually around $35 USD), most notably the Pi Zero, which costs just $5.

All over the world, people use the Raspberry Pi to learn programming skills, build hardware projects, do home automation, implement Kubernetes clusters and Edge computing, and even use them in industrial applications.

The Raspberry Pi is a very cheap computer that runs Linux, but it also provides a set of GPIO (general purpose input/output) pins, allows to control electronic components for physical computing and explore the Internet of Things (IoT).

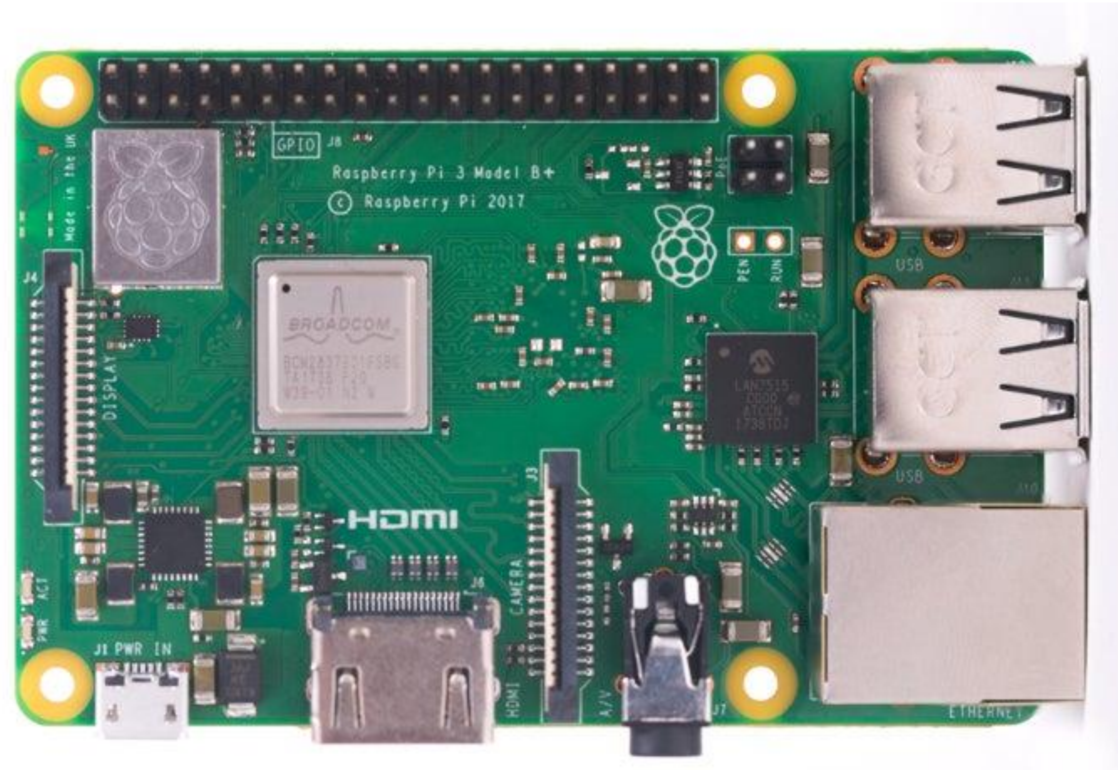

Fig. 26
Raspberry Pi 4 board

Some people buy a Raspberry Pi to learn to code, and people who can already code use the Pi to learn to code electronics for physical projects. The Raspberry Pi can open opportunities to create developer's/user's own home automation projects, which is popular among people in the open-source community because it puts the user in control, rather than using a proprietary closed system.

The Raspberry Pi Foundation works to put the power of computing and digital making into the hands of people all over the world. It does this by providing low-cost, high-performance computers that people use to learn, solve problems, and have fun. It provides outreach and education to help more people access computing and digital making—it develops free resources to help people learn about computing and making things with computers and also trains educators who can guide other people to learn.

Drawbacks –

An Arduino Nano equivalent board can be had for the same $5-10 and a slightly more functional U3 for a little more, but get all the I/O pins. But needs a power supply, might need an interface cable, and a PC is needed, Mac or Linux box run the programming support. On the other hand, the chip in the Nano and on the U3 (ATMega328P) can be had about $1 in small quantities and any of the 'AT Tiny' CPUs can be had for pennies if they will do the job.

One of my neighbours needs more 'screens' for their 3 primary school-aged kids trying to do remote schooling due to CV-19. They already had a Chromebook and she had her work-based PC and a home printer, but she needed PC for her own work. So, loaned them two old VGA's, Keyboards Mice, 2 RPi3's in cases, and PS. Now all kids have a screen and can print as needed on her PC.

So, it all depends on what is needed. If have a dedicated task, it might be perfect, but it might be overkill. If want to teach how to interface to hardware like sensors, it's a mixed bag compared to the smaller things. If already have the extras, it hard to beat as a small computer and teaching platform.

Conclusion –

It also doesn’t support Wi-Fi functionality, also it cannot be operated without a computer with specify minimum required system. Hence it also fails to qualify for the model device.

5.1.3. ESP32

ESP32 is a low-cost System on Chip (SoC) Microcontroller from Espressif Systems, the developers of the famous ESP8266 SoC. It is a successor to ESP8266 SoC and comes in both single-core and dual-core variations of the Tensilica’s 32-bit Xtensa LX6 Microprocessor with integrated Wi-Fi and Bluetooth.

The good thing about ESP32, like ESP8266 is its integrated RF components like Power Amplifier, Low-Noise Receive Amplifier, Antenna Switch, Filters and RF Balun. This makes designing hardware around ESP32 very easy as it requires very few external components.

Another important thing to know about ESP32 is that it is manufactured using TSMC’s ultra-low-power 40 nm technology. So, designing battery operated applications like wearables, audio equipment, baby monitors, smart watches, etc., using ESP32 should be very easy.

Espressif Systems released several modules based on ESP32 and one of the popular options is the ESP-WROOM-32 Module. It consists of ESP32 SoC, a 40 MHz crystal oscillator, 4 MB Flash IC and some passive components.

The good thing about ESP-WROOM-32 Module is the PCB has edge castellations. So, what third-part manufacturers do is take the ESP-WROOM-32 Module and design a break-out board for this module.

One such board is the ESP32 DevKit Board. It contains the ESP-WROOM-32 as the main module and also some additional hardware to easily program ESP32 and make connections with the GPIO Pins.

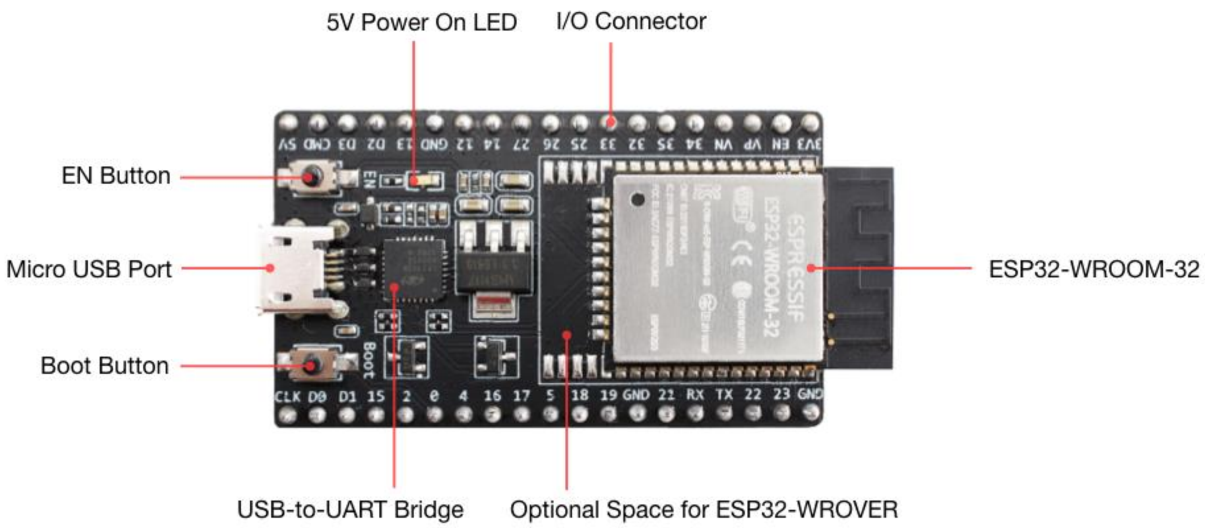

Fig. 27
ESP32 Devkit board

We will see what a typical ESP32 Development Board consists of by taking a look at the layout of one of the popular low-cost ESP Boards available in the market called the ESP32 DevKit Board.

The following shows the layout of an ESP32 Development Board which have been developed.

IMPORTANT NOTE: There are many ESP32 Boards based on ESP-WROOM-32 Module available in the market. The layout, pinout and features vary from board to board.

The board which have has 30 Pins (15 pins on each side). There are some boards with 36 Pins and some with slightly less Pins. So, double check the pins before making connections or even powering up the board.

Conclusion –

ESP32 is a good contender of the model device, as it supports Wi-Fi connectivity and wide range of device are supported.

5.1.4. ESP8266

NodeMCU is an open-source LUA based firmware developed for the ESP8266 wifi chip. By exploring functionality with the ESP8266 chip, NodeMCU firmware comes with the ESP8266 Development board/kit i.e., NodeMCU Development board.

Since NodeMCU is an open-source platform, its hardware design is open for edit/modify/build.

NodeMCU Dev Kit/board consist of ESP8266 Wi-Fi enabled chip. The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol. For more information about ESP8266, can refer to the ESP8266 Wi-Fi Module.

There is Version2 (V2) available for NodeMCU Dev Kit i.e., NodeMCU Development Board v1.0 (Version2), which usually comes in black coloured PCB.

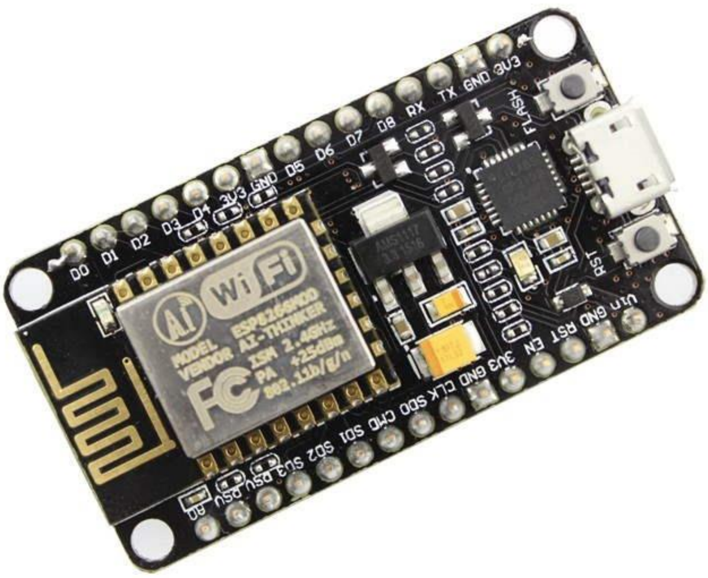

Fig. 28
NodeMCU Development Board/kit v1.0 (Version2)

NodeMCU Development board is featured with Wi-Fi capability, analogue pin, digital pins, and serial communication protocols.

To get started with using NodeMCU for IoT applications first it is needs to know about how to write/download NodeMCU firmware in NodeMCU Development Boards. And before that where this NodeMCU firmware will get as per our requirement.

There are online NodeMCU custom builds available using which it can easily get custom NodeMCU firmware as per the requirement.

After setting up ESP8266 with Node-MCU firmware, let’s see the IDE (Integrated Development Environment) required for the development of NodeMCU.

NodeMCU with ESPlorer IDE

Lua scripts are generally used to code the NodeMCU. Lua is an open-source, lightweight, embeddable scripting language built on top of C programming language.

For more information about how to write Lua script for NodeMCU refer to Getting started with NodeMCU using ESPlorerIDE

NodeMCU with Arduino IDE

Here is another way of developing NodeMCU with a well-known IDE i.e., Arduino IDE. It can also develop applications on NodeMCU using the Arduino development environment. This makes it easy for Arduino developers than learning a new language and IDE for NodeMCU

Conclusion –

The ESP8266 is cheaper than the ESP32. Although it doesn’t have as much functionalities, it works just fine for the majority of simple DIY IoT projects. Additionally, because it is “older” it is much more supported in terms of software, and might find help easier. However, it has some limitations when it comes to the GPIO mapping, and it might not have enough pins for what intend to do. If that's the case, ESP32 should be used.

But still for this model, the best suited device is "*NodeMCU ESP8266 Wi-Fi module*".

5.1.5. Common anode RGB LED

In a common anode configuration, the colours can be controlled by applying a low power signal or by grounding the RGB pins and connecting the internal anode to a positive lead of the supply as shown below

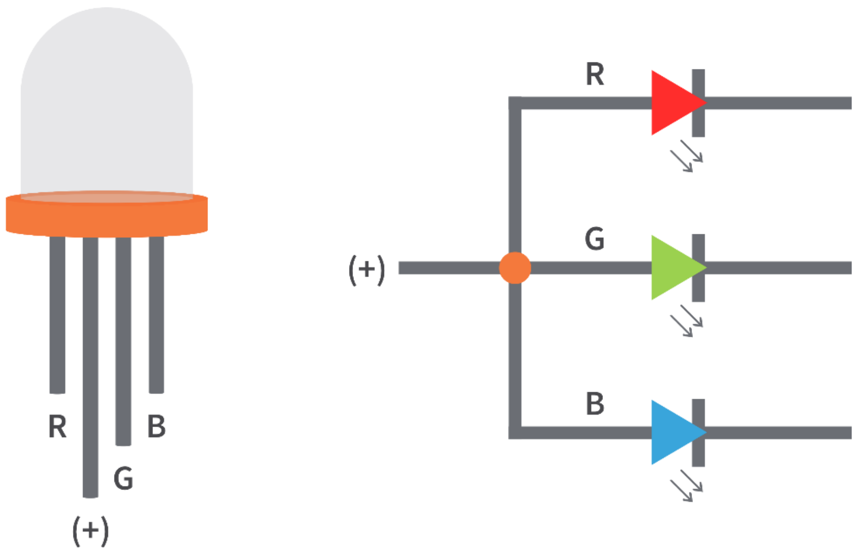

Fig. 29

Common anode RGB LED block and circuit

With a common anode, connect the anode to the +5v and each individual LED to a resistor each. Connect that resistor to an output pin. Then a write LOW to that pin will turn the LED on and a HIGH will turn it off. This is called current sinking.

5.1.6. Common cathode RGB LED

In common Cathode configuration, the colours can be controlled by applying a high-power input to the RGB pins and connecting the internal cathode to a negative lead of the supply as shown below

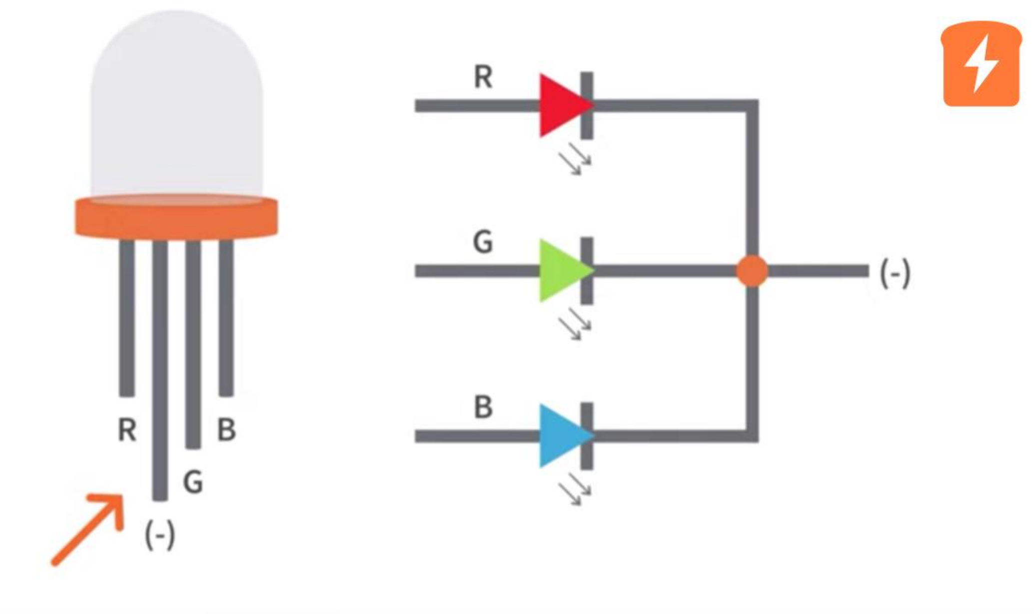

Fig. 30

Common cathode RGB LED and circuit

With a common cathode, connect the cathode to ground and connect each LED's anode through a resistor to the output pin. Then a HIGH turn it on. This is called current sourcing.

Conclusion-

As there is no absolute difference between the two types of RGB LEDs, but as per convenience and ease of use, the common cathode RGB LED has been chosen. As a common cathode RGB LED has only one ground terminal (GND), which makes the circuit easier and the remaining three legs will require positive voltage level as per required for different colour combinations.

5.2. Working

5.2.1. Overview

In this thesis the effects of mood lighting are studied in various zones created in the home according to the occupying pattern in that space.
By analysing some previous studies and market capitalization about mood & hue lighting, it can be stated that this lighting sector is very underutilized and also cost inefficient. So, with some study a Wi-Fi controlled LED bulb has been developed which can be operated using a webpage without internet. This is achieved through a Wi-Fi module ESP8266 IoT device.

Here a RGB LED is used, which takes input as 0 to MAX in each leg (RGB LED has 4 legs, 3 legs for R, G & B and 1 for GND). But computer/smartphone understands colours as 'rgb(255, 255, 255)' = white, which is the maximum output which can be provided by the RGB LED. Varying the values from 0 to 255 of each ‘r’, ‘g’ & ‘b’ in above will result in different colour combinations. These ‘rgb’ values then transferred to the NodeMCU, then it will be calibrated into 0 to MAX format and then will be given to each leg of the RGB LED.

All the necessary codes for the web page design and controlling functions are been embedded into the IoT device itself. It not only provides lighting condition for different moods but also can be used to produce any colour from 16 million different colours and of course the brightness of each colour can be adjusted as per our need. The mood lighting guide helps the user to understand use of each and every colour shade relating to the mood.

5.2.2. Steps followed

- Powering the ESP8266 Wi-Fi module using a type-2 USB mobile charged will generate a Wi-Fi hotspot signal, named “Prashant RGB”.

- This Wi-Fi hotspot signal is password protected, after connecting to this network created by the ESP8266, a webpage with address “http://rgb” can be opened.

- This webpage acts as a controlling board or colour picker which picks the precise colour and its corresponding colour code that user chooses from a range of 16 million different colours.

- This chosen colour and its colour code is then been transmitted back to the ESP8266 Wi-Fi module with absolute precision.

- The value of colour code ranges from 0 to 255 in hexadecimal number system for each R, G and B, which combines to make a particular colour, e.g., colour code for "Red" in hexadecimal is #FF0000 whereas the equivalent colour code in the range of 0 to 255 RGB system is rgb(255, 0 ,0). Observe the cleanliness of this RGB colour coding system. It exactly provides the corresponding colour value in a range which can easily be calibrated or amended as per designer's requirement.

- The colour picker used in the browser will always picks the values in RGB colour coding system (Not in Hexadecimal).
- The range is just a mere value for the ESP8266 Wi-Fi module. It operates through voltage levels only, i.e., it takes input as voltage and also the output as voltage in its GPIOs (General Purpose Input/Output pins).

- That's why internally those colour picker values must be calibrated in terms of voltage so that, the calibrated voltage when applied to the output pins of the ESP8266, which acts as the input for RGB LED.

- The calibration for the output voltage which will be provided to each output pin is carried out for each of the R, G and B values separately. And also need to make sure that the calibrated voltage values when provided on the RGB LED's legs should result in absolute and proper desired colour.

- When the appropriate voltage is applied to each leg of the RGB LED then it illuminates giving a prototype level success. And how the colour picker values is calibrated into proper voltages will be seen in the next chapter, i.e., in chapter 6.

5.2.3. Flow-chart of Working

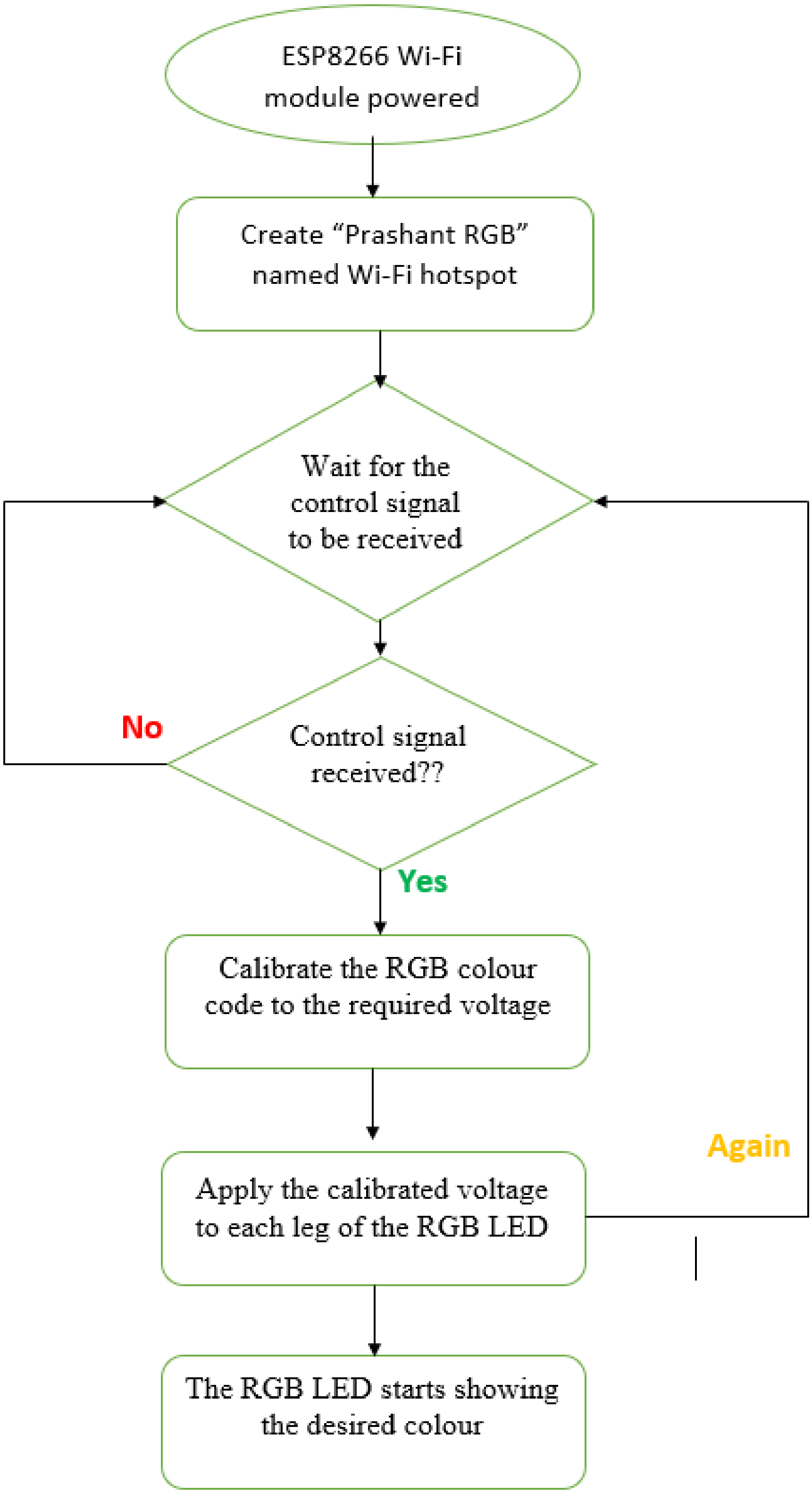

Fig. 31

Flow Chart of the internal working

CHAPTER 6

CALCULATIONS
&
CODE

6. Calculations and Code

6.1. Calculations

The colour picker picks the required colour value as RGB colour coded system, this ranges from 0 to 225 decimal values for each of R, G and B.

E.g., colour code for this **PINK** is: RGB (255, 192, 203).

But this value is of no use unless it has been converted to a certain voltage level which can be applied to each leg of the RGB led.

6.1.1. Formulas

This can be achieved using two formulas:

1. Colour correction –
   The range of each colour from R, G and B need to be converted in a range of 0 to 1024, for proper utilization of these values in terms of voltage.

   The formula thus formed is:

$$(\text{Color Correction})^{Red} = 1023 - \frac{value(Red) * value(Red)}{64}$$

$$(\text{Color Correction})^{Green} = 1023 - \frac{value(Green) * value(Green)}{64}$$

$$(\text{Color Correction})^{Blue} = 1023 - \frac{value(Blue) * value(Blue)}{64}$$

And the second formula is:

2. Calibrated Output Voltage –
After colour correction is done then that value is been used in this formula to set the output voltage for each leg just by using it as a voltage percentage setter.

The formula thus formed is:

- $(\text{Output Voltage})^{Red} =$

$$(Max\ Output\ Voltage) \times \left(1 - \frac{(\text{Color Correction})^{Red}}{1023}\right)$$

- $(\text{Output Voltage})^{Green} =$

$$(Max\ Output\ Voltage) \times \left(1 - \frac{(\text{Color Correction})^{Green}}{1023}\right)$$

- $(\text{Output Voltage})^{Blue} =$

$$(Max\ Output\ Voltage) \times \left(1 - \frac{(\text{Color Correction})^{Blue}}{1023}\right)$$

6.1.2. Example

It is better to understand this with an example, take **PINK** for this example having colour code RGB (255, 192, 203),

Colour Correction value Calculation –

Value (Red) = 255

Value (Green) = 192

Value (Blue) = 203

- Therefore, colour correction for "*Red*" will be:

$$(\text{Color Correction})^{Red} = 1023 - \frac{255 * 255}{64}$$
$$= 1023 - 1016$$
$$= 7$$

Colour correction value for" *Red*" is 7.

- Then, colour correction for "*Green*" will be:

$$(\text{Color Correction})^{Green} = 1023 - \frac{192 * 192}{64}$$
$$= 1023 - 576$$
$$= 447$$

Colour correction value for "*Green*" came out to be 447.

- And, colour correction for “*Blue*” will be:

$$(\text{Color Correction})^{Blue} = 1023 - \frac{203 * 203}{64}$$

$$= 1023 - 644$$

$$= 379$$

Colour correction value for “*Blue*” is 379.

Calibrated Output Voltage Calculation -

After calculation of all the colour correction values of red, green and blue, the next step will be to calculate Output Voltage that will be required for each leg of the RGB LED:

- First calculation for “*Red*” leg:

  Max Output Voltage = 3.3 volts

  $(\text{Color Correction})^{Red} = 7$

$$(\text{Output Voltage})^{Red} = (3.3\, volts) \times \left(1 - \frac{7}{1023}\right)$$

$$= (3.3\, volts) \times (0.993)$$

$$= 3.277\, volts$$

Output voltage to be applied to the “*Red*” leg is 3.277 volts.

- Calculation for "*Green*" leg:

  Max Output Voltage = 3.3 volts

  $(\text{Color Correction})^{Green}$ = 447

  $$(\text{Output Voltage})^{Green} = (3.3\, volts)\ \times \left(1\ - \frac{447}{1023}\right)$$
  $$= (3.3\, volts) \times (\ 0.563)$$
  $$=\ 1.858\ volts$$

Output voltage to be applied to the "*Green*" leg is 1.858 volts.

- Calculation for "*Blue*" leg:

  Max Output Voltage = 3.3 volts

  $(\text{Color Correction})^{Blue}$ = 379

  $$(\text{Output Voltage})^{Blue} = (3.3\, volts)\ \times \left(1\ - \frac{379}{1023}\right)$$
  $$= (3.3\, volts) \times (\ 0.629)$$
  $$=\ 2.077\ volts$$

Output voltage to be applied to the "*Blue*" leg is 2.077 volts.

So, the output voltages which will be applied to get the colour **PINK** are:

- $(\text{Output Voltage})^{Red} = 3.277\ volts$
- $(\text{Output Voltage})^{Green} = 1.858\ volts$
- $(\text{Output Voltage})^{Blue} = 2.077\ volts$

Which is equivalent to its colour code RGB (255, 192, 203).

The above calculations are all done internally by the ESP8266 Wi-Fi module when it receives a control signal.

These calculations as well as the calculated voltage which is applied on each leg takes a time of about $1/20^{th}$ of a second i.e., within 50ms.

As soon as the voltage is applied and the RGB LED starts producing the desired colour, the ESP8266 again gets ready to receive another control signal.

The next part is the most difficult one, which is how to make these calculations possible with the ESP8266 Wi-Fi module.

This can be achieved solely by writing proper code which allows these calculations to be done and also should support the webpage functionalities.

The next part will be the code and its understanding.

6.2. Code

```
#include <ESP8266WiFi.h>
#include <DNSServer.h>
#include <ESP8266WebServer.h>

const char *ssid = "Prashant RGB";
const char *password = "rgb007";
const byte DNS_PORT = 53;
const int redLED = 0;   //D3
const int greenLED = 4; //D2
const int blueLED = 5;  //D1
IPAddress apIP(192, 168, 1, 5);
DNSServer dnsServer;
ESP8266WebServer webServer(80);

String webpage = ""
"<!DOCTYPE html><html><head><title>RGB control</title><meta name='mobile-web-app-capable' content='yes' />"
"<meta name='viewport' content='width=device-width' /></head><body style='margin: 0px; padding: 0px;'>"
"<canvas id='colorspace'></canvas>"
"<button id='calmness' style='background-color: rgb(69, 179, 224); padding: 1rem; margin: 1rem; border-radius: 5px;'>Calmness</button>"
"<button id='warmth' style='background-color: rgb(225, 120, 45); padding: 1rem; margin: 1rem; border-radius: 5px;'>Warmth</button>"
"<button id='energetic' style='background-color: rgb(237, 44, 35); padding: 1rem; margin: 1rem; border-radius: 5px;'>Energetic</button>"
"<button id='freshness' style='background-color: rgb(184, 216, 8); padding: 1rem; margin: 1rem; border-radius: 5px;'>Freshness</button>"
"<button id='happiness' style='background-color: rgb(225, 225, 0); padding: 1rem; margin: 1rem; border-radius: 5px;'>Happiness</button>"
"<button id='love' style='background-color: rgb(235, 80, 94); padding: 1rem; margin: 1rem; border-radius: 5px;'>Love</button>"
"<button id='alert' style='background-color: rgb(0, 255, 254); padding: 1rem; margin: 1rem; border-radius: 5px;'>Stay Alert</button>"
"<button id='exciting' style='background-color: rgb(255, 0, 254); padding: 1rem; margin: 1rem; border-radius: 5px;'>Exciting</button></body>"
"<script type='text/javascript'>"
```

```
"(function () {"
" var canvas = document.getElementById('colorspace');"
" var energetic = document.getElementById('energetic');"
" var happiness = document.getElementById('happiness');"
" var calmness = document.getElementById('calmness');"
" var warmth = document.getElementById('warmth');"
" var freshness = document.getElementById('freshness');"
" var love = document.getElementById('love');"
" var alert = document.getElementById('alert');"
" var exciting = document.getElementById('exciting');"
" var ctx = canvas.getContext('2d');"
" function drawCanvas() {"
" var colours = ctx.createLinearGradient(0, 0, window.innerWidth, 0);"
" for(var i=0; i <= 360; i+=10) {"
" colours.addColorStop(i/360, 'hsl(' + i + ', 100%, 50%)');"
" }"
" ctx.fillStyle = colours;"
" ctx.fillRect(0, 0, window.innerWidth, window.innerHeight);"
" var luminance = ctx.createLinearGradient(0, 0, 0, ctx.canvas.height);"
" luminance.addColorStop(0, '#ffffff');"
" luminance.addColorStop(0.05, '#ffffff');"
" luminance.addColorStop(0.5, 'rgba(0,0,0,0)');"
" luminance.addColorStop(0.95, '#000000');"
" luminance.addColorStop(1, '#000000');"
" ctx.fillStyle = luminance;"
" ctx.fillRect(0, 0, ctx.canvas.width, ctx.canvas.height);"
" }"
" var eventLocked = false;"
" function handleEvent(clientX, clientY) {"
" if(eventLocked) {"
" return;"
" }"
" function colourCorrect(v) {"
" return Math.round(1023-(v*v)/64);"
" }"
" var data = ctx.getImageData(clientX, clientY, 1, 1).data;"
```

```
" var params = ["
" 'r=' + colourCorrect(data[0]),"
" 'g=' + colourCorrect(data[1]),"
" 'b=' + colourCorrect(data[2])"
" ].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);"
" req.send();"
" eventLocked = true;"
" req.onreadystatechange = function() {"
" if(req.readyState == 4) {"
" eventLocked = false;"
" }"
" }"
" }"
" canvas.addEventListener('click', function(event) {"
" handleEvent(event.clientX, event.clientY, true);"
" }, false);"
" canvas.addEventListener('touchmove', function(event){"
" handleEvent(event.touches[0].clientX, event.touches[0].clientY);"
"}, false);"
" energetic.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 7,'g=' + 1023,'b=' + 1023].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" love.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 15,'g=' + 1023,'b=' + 1005].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" calmness.addEventListener('click', () => {"
```

```
" if (eventLocked) {return;}"
" var params = ['r=' + 1023,'g=' + 7,'b=' + 951].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" warmth.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 7,'g=' + 1012,'b=' + 1023].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" freshness.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 494,'g=' + 294,'b=' + 1022].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" happiness.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 7,'g=' + 984,'b=' + 1023].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" alert.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 1023,'g=' + 7,'b=' + 15].join('&');"
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" exciting.addEventListener('click', () => {"
" if (eventLocked) {return;}"
" var params = ['r=' + 7,'g=' + 1023,'b=' + 15].join('&');"
```

```
" var req = new XMLHttpRequest();"
" req.open('POST', '?' + params, true);req.send();eventLocked = true;"
" req.onreadystatechange = function () {"
" if (req.readyState == 4) {eventLocked = false;}}}, false);"
" function resizeCanvas() {"
" canvas.width = window.innerWidth;"
" canvas.height = window.innerHeight;"
" drawCanvas();"
" }"
" window.addEventListener('resize', resizeCanvas, false);"
" resizeCanvas();"
" drawCanvas();"
" document.ontouchmove = function(e) {e.preventDefault()};"
" })();"
"</script></html>";

//////////////////////////////////////////////////////////////////////////
///////////////////////

void handleRoot() {
// Serial.println("handle root..");
String red = webServer.arg(0); // read RGB arguments
String green = webServer.arg(1);
String blue = webServer.arg(2);

if((red != "") && (green != "") && (blue != ""))
{
  analogWrite(redLED, 1023 - red.toInt());
  analogWrite(greenLED, 1023 - green.toInt());
  analogWrite(blueLED, 1023 - blue.toInt());
}


Serial.print("Red: ");
Serial.println(red.toInt());
Serial.print("Green: ");
```

```
Serial.println(green.toInt());
Serial.print("Blue: ");
Serial.println(blue.toInt());
Serial.println();

webServer.send(200, "text/html", webpage);
}

//////////////////////////////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////////////////////////////

void setup() {

pinMode(redLED, OUTPUT);
pinMode(greenLED, OUTPUT);
pinMode(blueLED, OUTPUT);

analogWrite(redLED, 0);
analogWrite(greenLED, 0);
analogWrite(blueLED, 0);

delay(1000);
Serial.begin(115200);
Serial.println();

WiFi.mode(WIFI_AP);
WiFi.softAPConfig(apIP, apIP, IPAddress(255, 255, 255, 0));
WiFi.softAP(ssid);

// if DNSServer is started with "*" for domain name, it will reply with provided IP to all DNS request
dnsServer.start(DNS_PORT, "rgb", apIP);

webServer.on("/", handleRoot);

```

```
webServer.begin();

testRGB();
}

/////////////////////////////////////////////////////////////////////////

void loop() {
dnsServer.processNextRequest();
webServer.handleClient();
}
/////////////////////////////////////////////////////////////////////////

void testRGB() { // fade in and out of Red, Green, Blue

analogWrite(redLED, 0); // R off
analogWrite(greenLED, 0); // G off
analogWrite(blueLED, 0); // B off
fade(redLED); // R
fade(greenLED); // G
fade(blueLED); // B
}

/////////////////////////////////////////////////////////////////////////

void fade(int pin) {
for (int u = 0; u < 1024; u++) {
analogWrite(pin, u);
delay(1);
}
for (int u = 0; u < 1024; u++) {
analogWrite(pin, 1023 - u);
delay(1);
}
}
```

After a long 7 page of code, now time to understand which part does what by breaking this whole code into small segments.

- Line number 1 to 13 includes header files for Wi-Fi and the Hotspot name with password, IP address and PIN description for the RGB LED power output.
- From line 15, the web development part starts which first describes the meta data for the webpage.
- Then Mood lighting buttons are been made for the bottom of the screen.
- After that function starts, which reads the received control signal and sends to another function for its calibration into a voltage.
- Some functions cast out the 16 million colour screen to slide on the cursor and fingers.
- Then even listener functions are there to communicate between hardware and software in real time.
- Then comes the Colour Correction function, which apples the formula as discussed in the previous chapter for each of the RGB legs of the LED.

- That Colour Correction functions output goes into the Calibrated Output Voltage Functions.

- The Output Voltage functions decides what should be the proper output for that particular-coloured leg. Here ends the work of the web development part.

- The next part is to establish a connection between the hardware and the software. It starts from line number 155.
- After that the ESP8266 configuration remains, which also need to be addressed.

- Each pin that needs to be used has to be defined, this starts from line no. 183.

- Code written from line number 219 actually provides the calculated output voltages to the designated output pins which goes directly to the legs of the RGB LED.

- After all these operations the program goes back to its original state of waiting for the input control signal to be received.

- And this cycle goes on whenever user change the colour from the output screen of smartphone or PC.

CHAPTER 7

RESULT ANALYSIS

7. Result Analysis

7.1. Hue light analysis

Beside other benefits, it has been observed that hue lighting can drastically reduce the electricity bills. How much is this above sentence true, need to be find out:

The ZigBee radio does use a minimal amount of power, but it is not zero (it's ~0.4 W). On top of that, the Hue lights needs a hub/bridge to connect the ZigBee network to user's Wi-Fi (and/or the internet). This uses approx. 1.5 W (it likely depends on which version, but that seems to be the ballpark figure). So, to be fair, you'd need to divide that bridge power consumption across user's light bulbs.

So, if had only one light bulb, the *de facto* standby power per light bulb would be ~ 2 W, whereas if had 50, the de facto per bulb would be ~0.43 W.

This power consumption is added on top of the power consumption for actually using the light bulb, and is on being used 24/7 (unless unplug/cut the power, but then why would someone even get smart bulbs?).

Something a Hue bulb can do, that a "regular" cannot. It can change colour, and it is dimmable (well, depending on the setup, a regular bulb could do that).

A "regular" LED bulb is often somewhere between 6 and 10 W. A Philips hue bulb (the colour option) will use up to 6.1 W at cool white, maximum brightness, but only ~ 2.5 W if red at maximum brightness, and as low as 1.7 W if on 50% brightness, and using "warm white" light.

So really, it depends.

It depends on how someone uses them. It depends on how much of the time a bulb would be "on", and on what setting.

Let's say the "regular" bulb is equivalent to the 6.1 W of a maximum brightness, cool white light Hue bulb (so 5.7 W, since subtracted the 0.4 W that's for the ZigBee radio).

If the user has that bulbs on for 15% of the time, on average, and someone have 20 bulbs in users' home, but half of the time, the hue bulbs were on the 50% brightness, warm white light setting, then for regular bulbs for… let's say a year (8760 hours):

$20*8760h*0.15*5.7W \approx 150kWh$$20*8760h*0.15*5.7W \approx 150kWh$

For the hue:

$20*8760h*(0.075*6.1W+0.075*1.7W)$
$\approx 102kWh$$20*8760h*(0.075*6.1W+0.075*1.7W) \approx 102kWh$
BUT! still have the bridge, eating up the 1.5 W 24/7, so

$102kWh+8760h*1.5W \approx 116Wh.$$102kWh+8760h*1.5W \approx 116Wh.$
So, all in all, it's almost 2.5 times more power for the Philips Hue.

But if, however, user had 5 bulbs:

For "regular":

$5*8760h*0.3*5.7W \approx 37.4Wh$$5*8760h*0.3*5.7W \approx 37.4Wh$
For the hue:

$5*8760h*(0.15*6.1W+0.15*1.7W)$
$+8760h*1.5W \approx 38.8kWh$$5*8760h*(0.15*6.1W+0.15*1.7W)$
$+8760h*1.5W \approx 38.8kWh$
So here the Hues would consume slightly more.

The point is, it all depends on how many bulbs, and how the user uses them. User can save energy with smart lights (though given the upfront cost, you’ll never save money), but given the need to the bridge, you’d need a significant number of them, and you’d need to use them in an efficient way.

7.2. Mood light analysis

7.2.1. Effects

Our natural clock is in the part of the brain called the *hypothalamus*, which is linked to photoreceptors located throughout the body (such as the retina). These receptors are responsible for synchronizing our internal clock with the light humans absorb during the day. Understanding the circadian cycle is essential because it affects the rhythms of the human body and influences sleep, mood, wakefulness, digestion, temperature control, and even cell renewal. Research shows that an adequate amount of light improves mood and energy levels, while poor lighting contributes to depression and other deficiencies in the body. The amount and type of lighting directly affect concentration, appetite, mood, and many other aspects of daily life.

The colour temperature of light likewise greatly affects the human body. Typically depicted in Kelvin (K), the higher the colour temperature, the brighter and cooler the light will be. In this case, 'warm' and 'cold' don't refer to the physical heat of the lamp, but to the tone or colour of the light. Warm lights make the environment feel more welcoming and relaxing, while cooler lights make the environment more stimulating - they make someone feel more alert, more focused, and can increase productivity levels. It's also believed that blue light reduces levels of the sleep-related hormone melatonin, making humans feel more awake. Computers and mobile screens emit a lot of blue light, so that last email check before bed can make our sleep a lot less restful. But when used intelligently, blue light can be ideal for those spaces where the mind needs to work at full speed, such as meeting rooms, industrial kitchens, and even factories, where high concentration is expected.

Experts agree that taking advantage of sunlight during the day and avoiding direct exposure to cold or blue light at bedtime can improve quality of sleep and positively affect people's well-being and productivity. And although it's impossible to control the lighting of all the environments and spaces that humans will inhabit, being aware of the impacts of lighting on our body can make people think twice about some of the choices would otherwise make in a heartbeat - whether it be buying that lamp for sale in the supermarket, or even just checking our phone one last time before bed.

Here these are the samples of the outcome of this thesis work, this below figure 32. A is the example of Mood Lighting Design and the figure 32. B is the example of Hue Lighting Design.

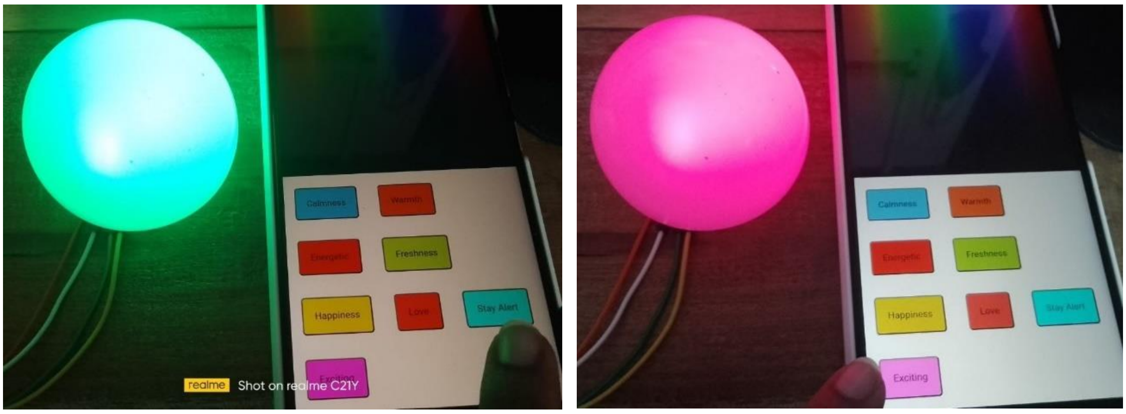

Fig. 32.A

Mood Lighting- on left: Stay Alert, on right: Exciting

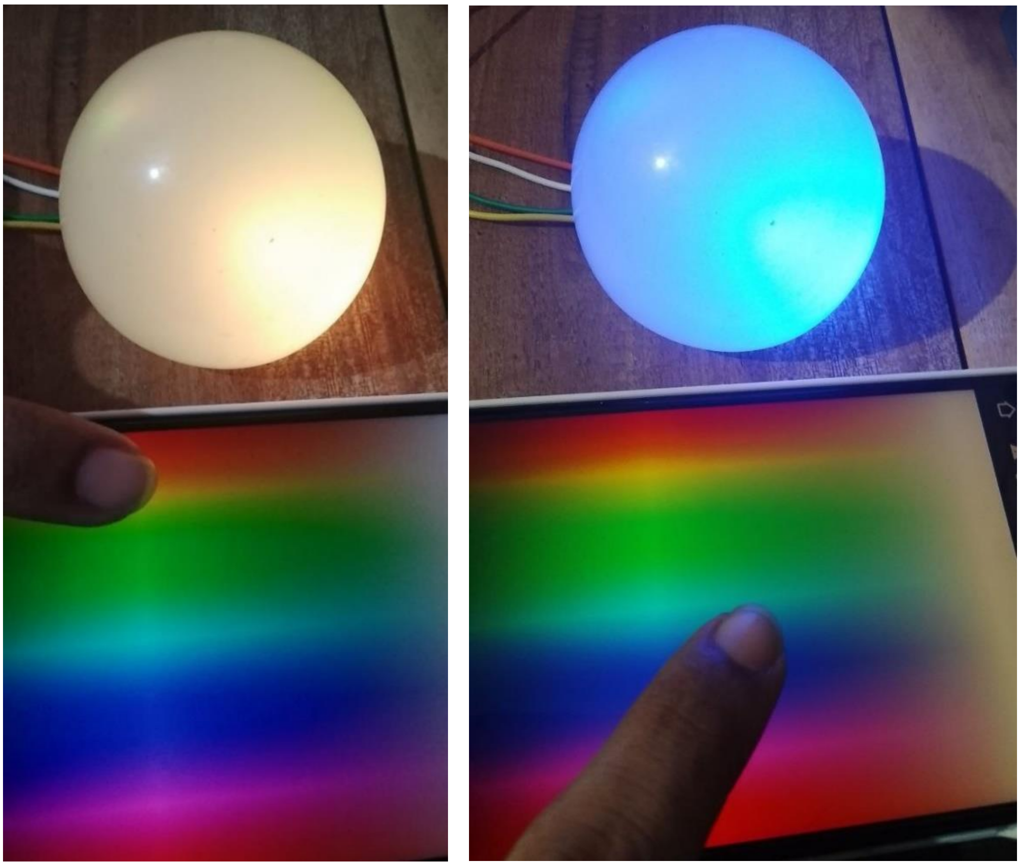

Fig. 32. B

Hue Lighting- on left: pale yellow, on right: blue

7.2.2. Other uses

Light therapy—or phototherapy, classically referred to as heliotherapy—is a method recognized by scientific medicine for the treatment of various diseases. It includes exposure to outdoor daylight or specific indoor artificial light sources.

The care guideline for unipolar depression recommends light therapy especially for depression that follows a seasonal pattern (seasonal affective disorder). There is tentative evidence to support its use to treat depressive disorders that are not seasonally dependent. As a treatment for disorders of the skin, the second kind of light therapy, called ultraviolet light therapy, is meant to treat neurodermatitis, psoriasis, acne vulgarize, eczema and neonatal jaundice.

CHAPTER 8

CONCLUSION
&
FUTURE SCOPE

8. Conclusion

8.1. Hue and Mood lighting design conclusion

- In this thesis work it is seen that how a low cost IoT based mood light and hue light system can be achieved. With all its benefits and easy to use methods, it stands on top of all the various products available in the market. It is not bound to only a specific OS user, it can be used by any low-end smartphone as well as PCs.

- And then the Mood lighting has its own advantage, being able to control light for any mood actually helps a person to live in harmony with themselves. Having a mood light setting is not bad idea.

- The use of hue lighting as well as mood lighting is not limited nowadays, with initial upfront installation fees it can be easily achieved with proper guidance.

- Out of the total benefits that Mood lighting brings, the main and most used fields are - work mood enhancement, fight depression, can cut down craving and can be used to get a better night sleep.

8.2. Future Scope

Everyone knows Smart Lighting do have a very bright future ahead, but still, it faces some challenges as, acceptance by the users, thinking beyond conventional methods and huge installation charges.

But still its future is brighter than any other industry in coming years. The more people will educate about these things the more they understand the need of Mood and Hue lighting in their daily life.

In near future the Smart Lighting and Hue/Mood Lighting will look certainly like this –

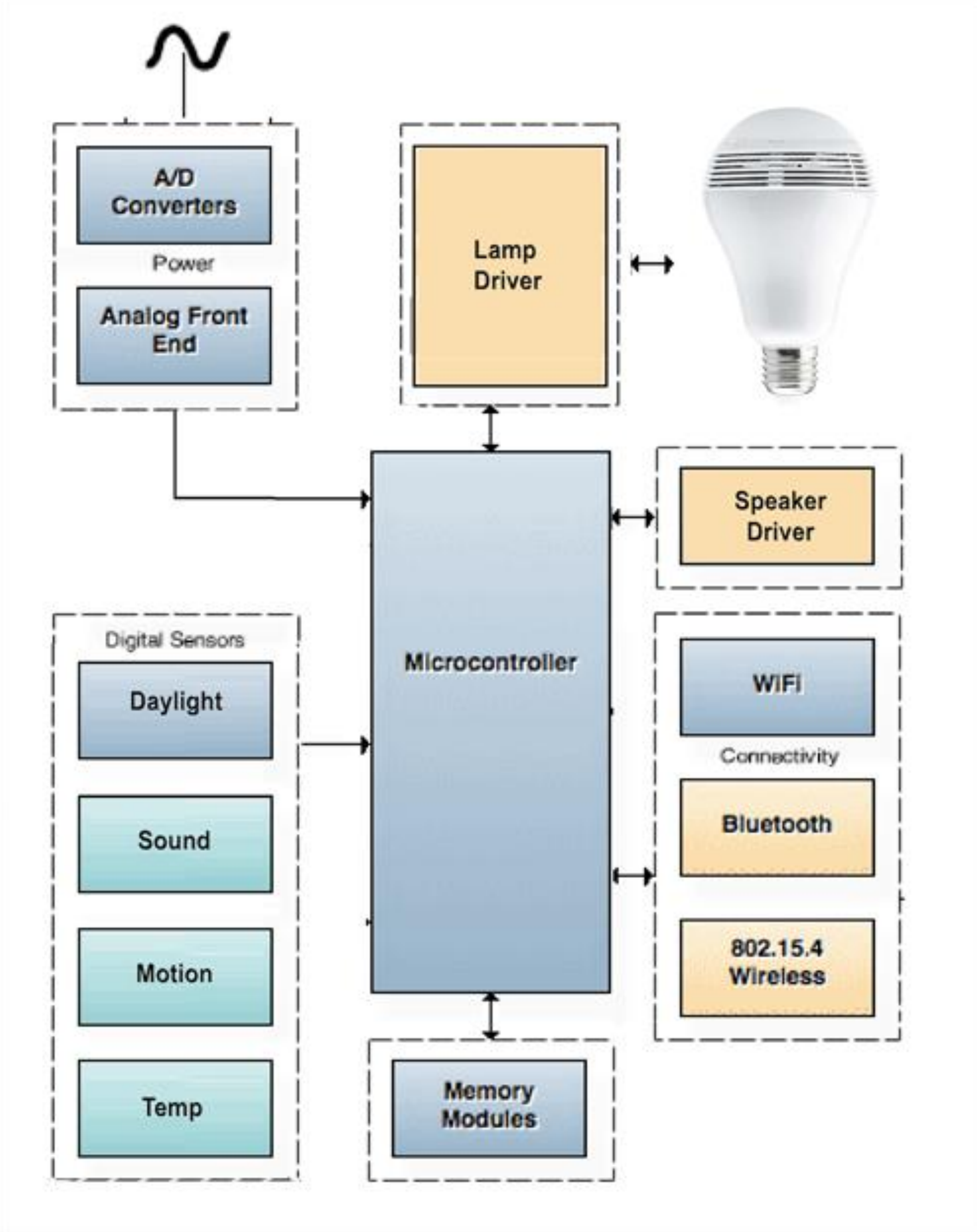

Fig. 33

Future plan for IoT based smart lighting with sensors

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