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Flicker Meter

Handbook by UPRtek

FLICKER

UPRtek

MF250N

Flicker Meter with Spectrometer

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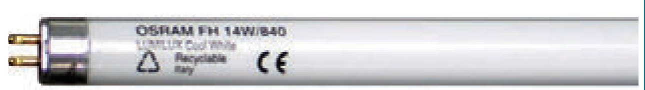
Never knew why...

Fluorescent Lamp



Sarah, a friend of mine who was born in the 1940s, said that she didn't like go ing to school as a child. Of course, I asked why, and she proceeded to tell me that it was because she would get headaches all the time, but she never knew why.

What is Flicker ?

Insidious and confounding

Flicker is the pulsating or fluctuating light phenomenon of artificial light sources (incandescent, fluorescent, LED bulbs etc.). Most types of artificial lighting will have the potential to emit flicker when connected to the wall sockets or to the power mains in your home or business. For most modern lighting environments, you probably will not see any noticeable flickering. However, just because you can't see flicker, doesn't mean that there isn't any flicker.

All Light Bulbs Flicker

Incandescent Bulb **Fluorescent Bulb** **LED Bulb**

Some Terminology

TLA or Temporary Light Artifact is a term that you will run across in Flicker literature. It refers to unusual light phenomena from light sources.

Stroboscopic Effect refers to the visual distortion of moving objects (similar to wagon wheel effect covered later) - it is an indirect consequence of flickering lights. Both Flicker and Stroboscopic Effects are categorized under TLA.

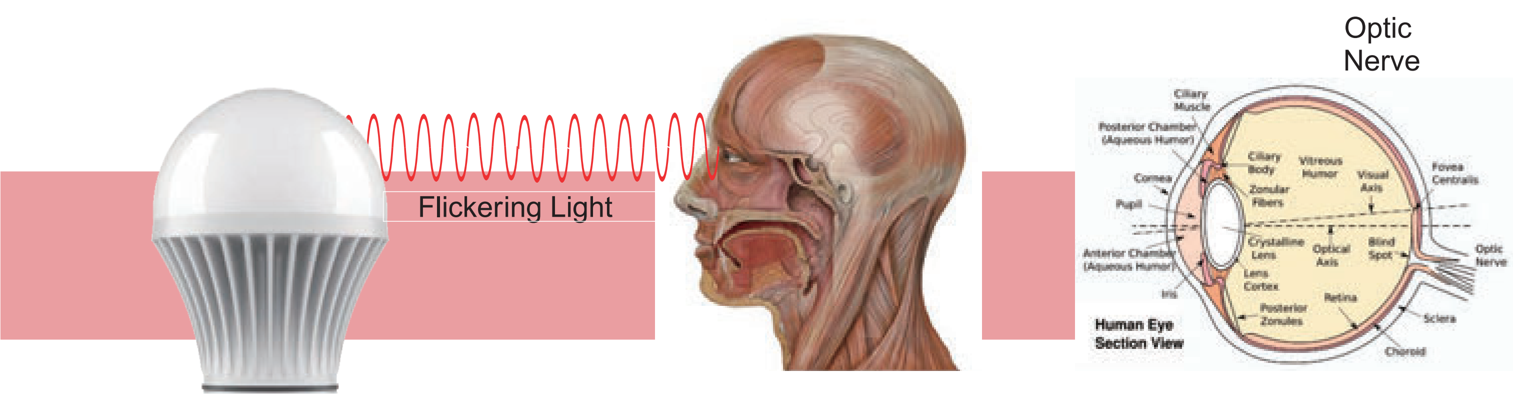
The Adverse Effects of Flicker

Suspicions about the adverse effects from flicker (visible and non-visible) have been around ever since fluorescent lighting was incorporated into the work place (around the 1950s).

The effects of flicker have been well studied and include, but are not limited to, headaches, migraines, eye strain, fatigue, and even epileptic seizures.

Even if flicker cannot be visually seen, flickering light can still enter through your eyes, reaching our retinas, traveling the neural circuitry to your central nervous system (brain), where they pound your senses, potentially wreaking havoc.

In short, flicker can present a silent, most times invisible and insidious problem.



Patrick J. Lynch, Medical Illustrator, C. Carl Jaffe MD - CC-BY-2.5 Generic

Not everyone is susceptible to light flicker, and it's hard to quantify what percentage of the population is actually light flicker sensitive. At best, we found a source that estimates 1 in 4000 individuals suffer from photosensitive epileptic seizures (light sensitive seizures).

It is also hard to quantify exactly what levels of flicker exceed thresholds for safety and health. Our visual senses and central nervous systems are complex and vary from person to person. Differences in age, visual acuity and bodily chemistry vary greatly and exacerbate the problem even more.

Ambient lighting from multiple sources also adds to the complexity of Flicker Do multi-light environments reduce flicker, increase flicker or both?

What level of flicker severity can be considered safe for such a diverse, fluid and multi-faceted environment? In short, it is an extremely difficult problem to get your arms around.

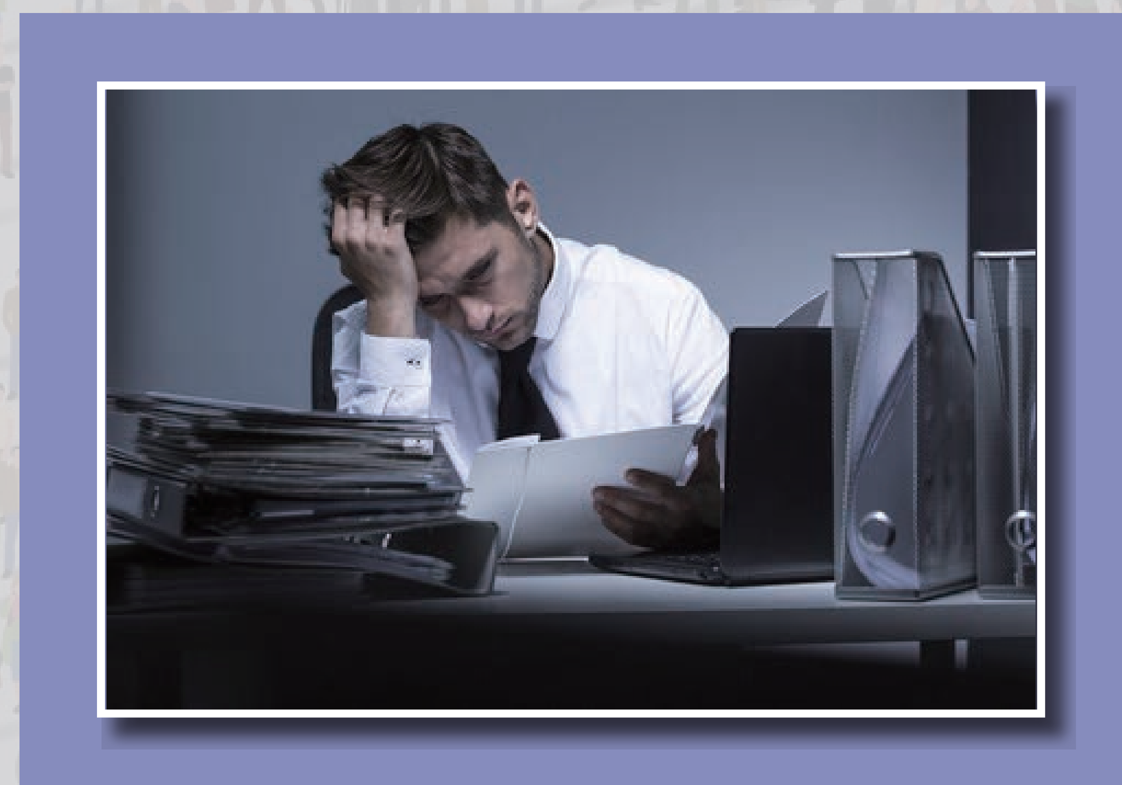
1 IN 4000

If only 1 in 4000 individuals suffer from photosensitive epileptic seizures, which is a mere .025 percent of the population, why worry?

First, are you willing to risk even a remote possibility of something as catastrophic as an epileptic seizure occurring on your premises, especially if it can be almost completely avoided.

Second, aside from seizures, there are lots of gray areas of flicker induced health problems that are not clearly defined, although well documented and studied (headaches, migraines, autistic behavioral response, work fatigue).

Third, it's not only the occasional headaches or migraines. Other studies claim that productivity increases 8% in flicker free environments with general mood ratings (well being, happiness levels) also increasing 33%. This should be a concern for companies for every day of the week and every working hour of the day.

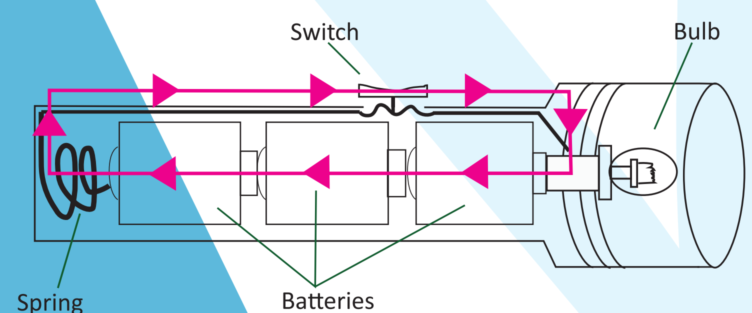


What causes flicker?

There are several reasons why a light might flicker, but let's start at the root.

DC - Flashlights do not flicker

Have you heard of Direct Current and Alternating Current? Almost all of the electricity available to consumers will be in one form or the other. With Direct Current, electricity flows in one direction, as in your flashlight. In a flashlight, there is a simple negative and positive wiring connected to the +/- poles of a battery - the electricity just flows around and around, all the while lighting that little bulb in a con tinuous flicker-less stream.



The adverse effects of flicker are not always black and white, but detection and prevention almost certainly is. We have the tools to measure it and the technology eliminate it.

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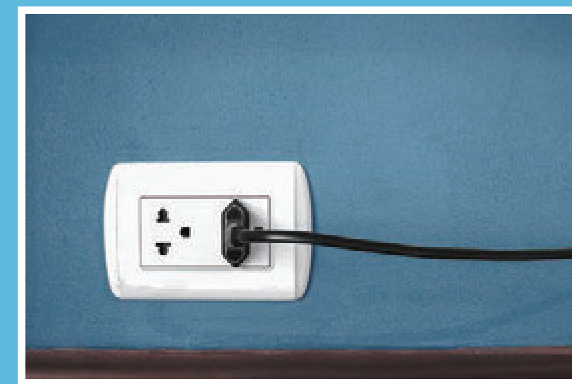
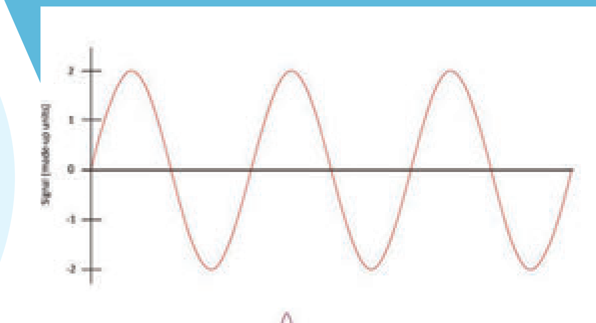
AC vs. DC

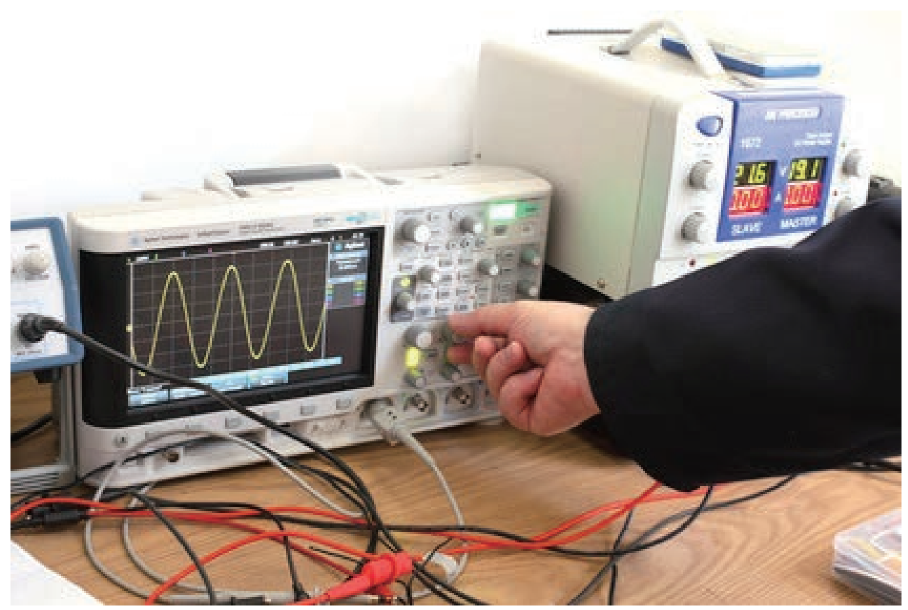
AC - Wall Sockets & Flicker

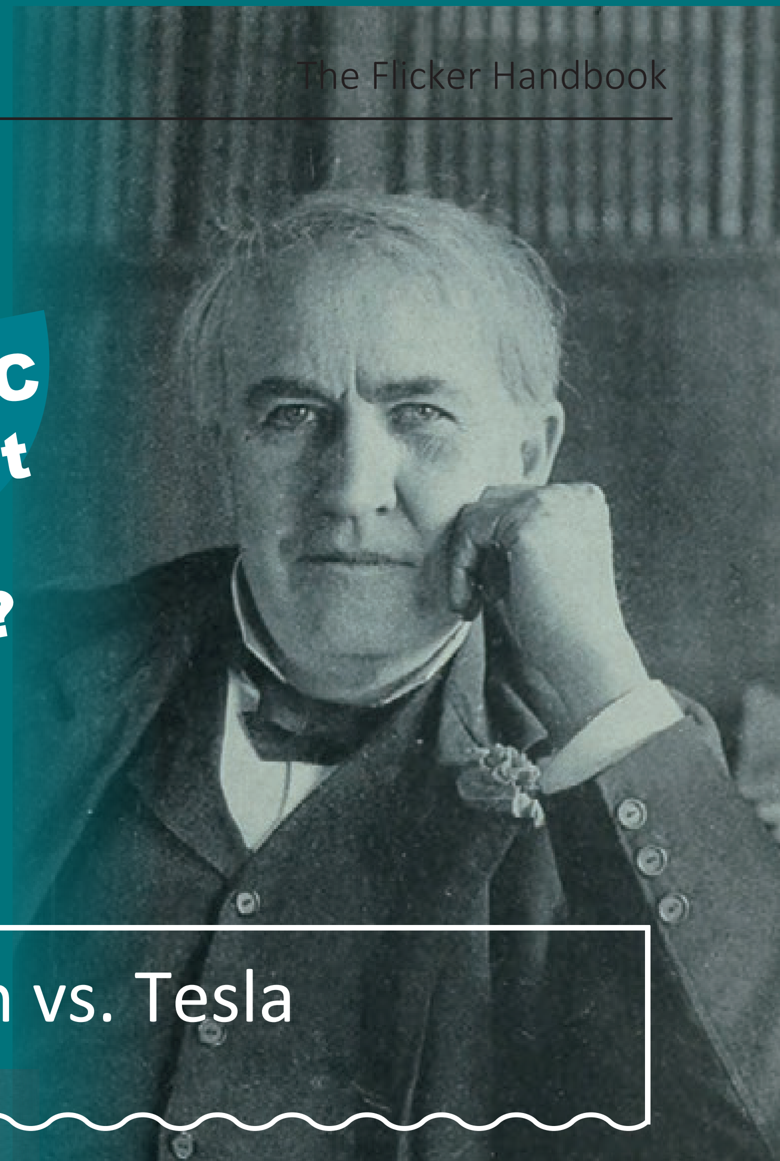


AC or Alternating current is the electricity that is used in our homes and businesses via power mains and wall sockets. Alternating Current is so called because the current alternately changes direction, back and forth with periodic fluctuating consis tency. When you plug your lamp into the wall socket, it is using Alternating Current and it is this cyclic reversal of current that causes the pulsating characteristics of flicker.



An oscilloscope connected to a home power mains can show a sine wave that reflects the alternating aspects of AC over time.



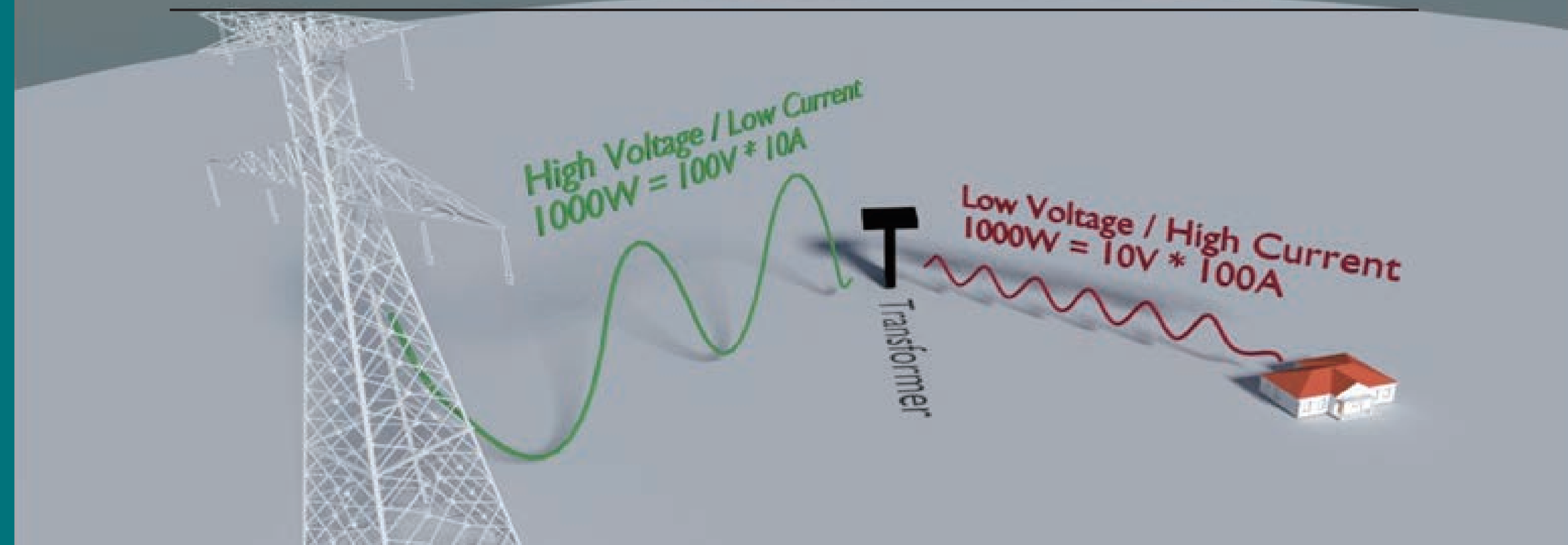


If DC produces no flicker and AC does, why didn't we just make everything DC?

Edison vs. Tesla

War on Currents

It was the great debate of the late 19th century, whether to use DC or AC as a means to distribute electricity over a wide area. It was called the "War of Currents" pitting Thomas Edison (DC proponent) and Nikolai Tesla (AC proponent).



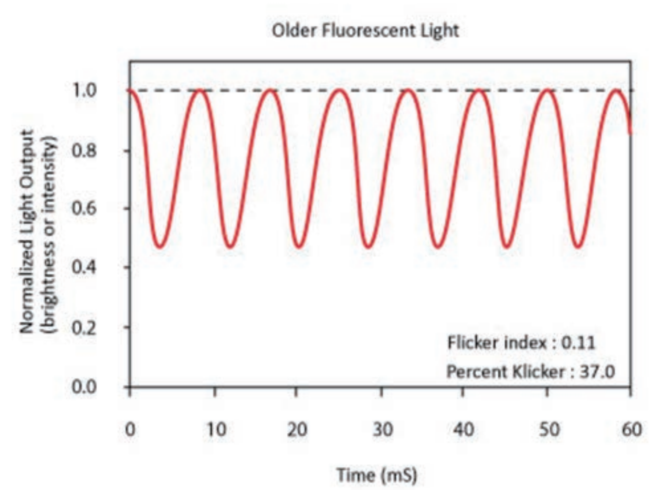
There is a good reason for using AC, and like many things, it is driven in part by economics. AC allows voltage to be easily increased or decreased by a device called a transformer. When delivering power over long distances, it's best to transmit power with high voltages and lower currents (as opposed to low voltages and high currents) which is much more efficient because lower currents reduce the loss of heat energy during transit over long distances. Once the AC electricity arrives at your business or home, the voltage can be easily stepped back down (again using AC) for safe usage in homes and businesses.
It is the alternating aspect of AC that makes it practical for delivery. But this same aspect is also causes flickering lights.

Learn about Voltage vs. Current (see video)
http://www.diffen.com/difference/Current_vs_Voltage

UPRtek MF250N

You can measure the flicker in a light with a Flicker Meter that can display a light wave.

A light wave (right) simply a graphic that represents a flickering light at it's highest and lowest intensities - you can see how it is influenced by the cyclic patterns of AC current flow. The height, shape, frequency, width of the wave all are characteristics that determine the extent of flicker. You should probably familiarize yourself with this diagram because it will be used often throughout. We'll learn more about light waves later.



Other factors that influence flicker

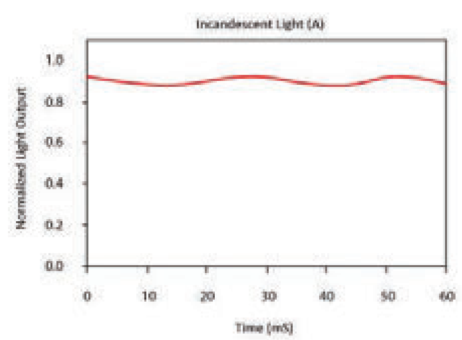
In addition to AC, there are other factors that will either induce or affect flicker. Some high energy consuming appliances such as refrigerators or welding equipment attached to your wall socket or mains may drain the electricity in your circuitry and change the characteristics of the light wave in such a way to induce flicker.

Dimmers can influence the way light is output from a light bulb also affecting flicker (we will cover dimmers later).

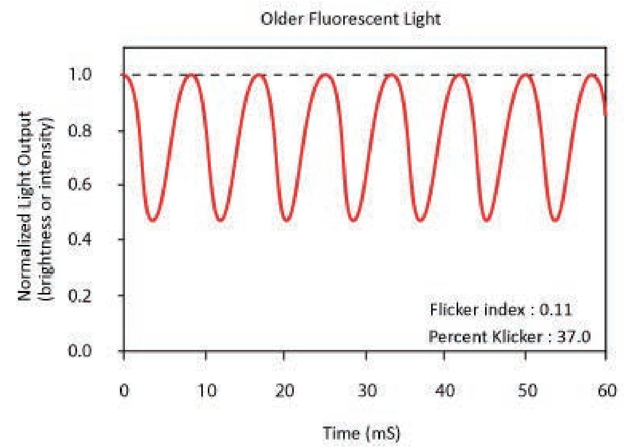
Why some types of lights flicker more than others?

Let's say a word about the traditional incandescent lights, which certainly flicker, but for the most part is negligible. These lights have a filament which glows when it is heated with the flow of electricity. They usually will not have flicker issues because the heat and light from the filament lingers, like a simmering red hot iron, long past each peak and trough of a flicker cycle. The AC current still fluctuates through an Incandescent bulb, but the flicker is washed out by the long continuous burn of the filament.

Below is the light wave for an incandescent light. Notice that there is still some flicker, but hardly noticeable because of the shallow difference between high and low intensities.

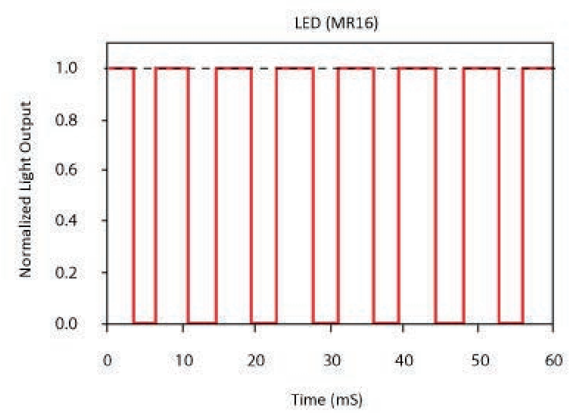


With fluorescent and LED bulbs, light is produced differently. There is no filament to burn – instead, light is produced by the phenomenon of jumping electrons (see UPRtek Survival Handbook on explanation) that turn off and on light almost instantaneously (fluorescent in milliseconds, LED in microseconds). Below is a light wave for a fluorescent light.



Fluorescent Bulb

Below is a light wave for an LED light. Notice the sharp corners that drop off between high and low intensities, indicative of sudden on/off characteristic of LEDs (faster than Fluorescent). (note that LEDs can be fitted with "drivers", covered later, that can quite drastically change the shape of the wave).



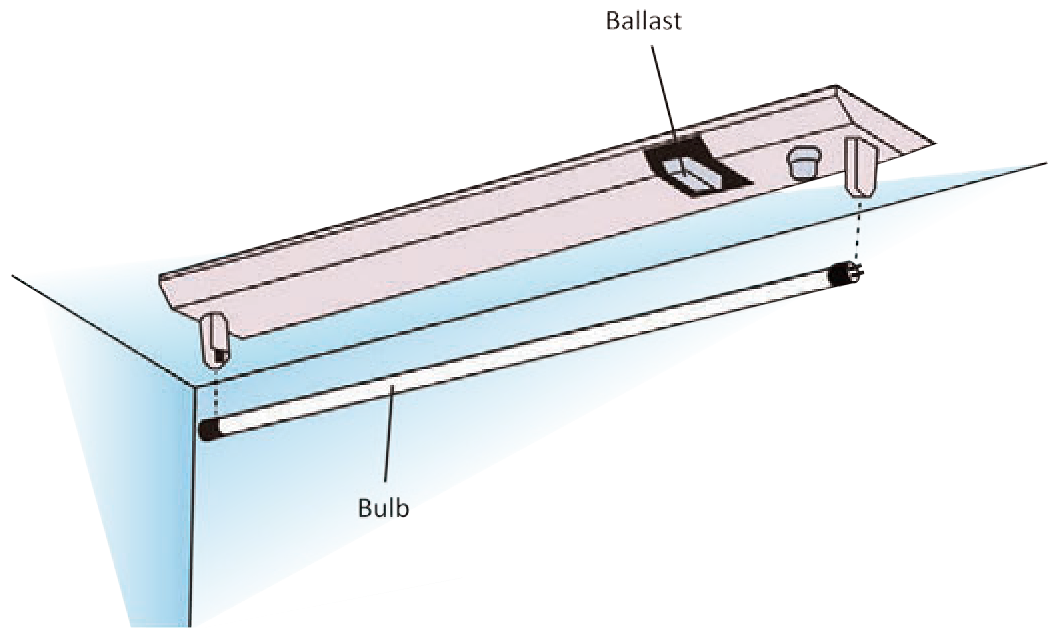
LED Bulb

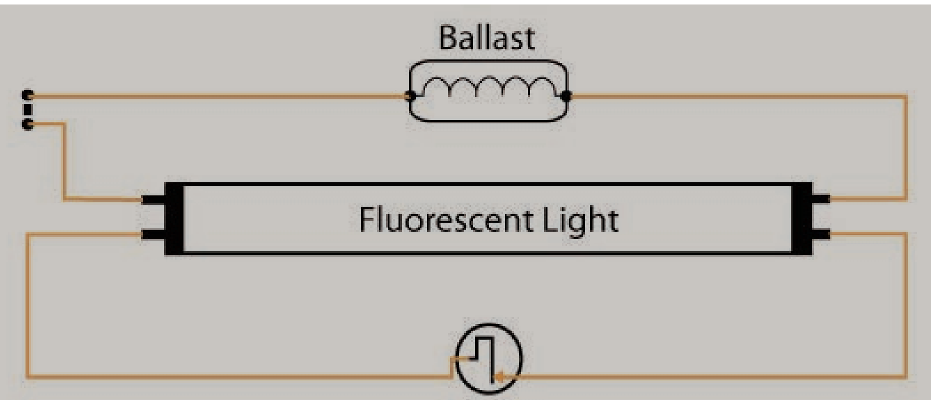
How do bulbs handle light flicker?

Fluorescent Lights and Flicker - The battle won

Fluorescent Lights have, what is called a ballast, that limits/reduces the current that runs through the light to protect it against excessive or surging current.

These ballasts are built into the circuitry of the bulb itself or is an independent unit able to control several lights. The older fluorescent lights have what is called a **Magnetic Ballast**, which uses a simple construction (single coil) to mitigate surges in current flow, but does not address AC current. With these ballasts you can get flickering light and even some buzzing.





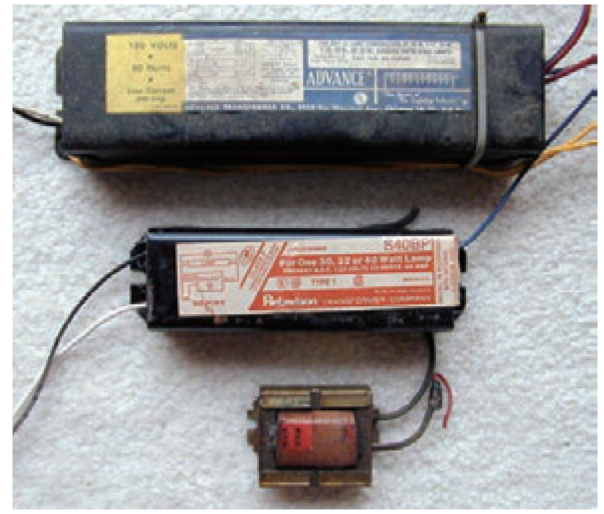
An **Electronic Ballast is** a slightly more sophisticated construction (multiple coils), that can increase the frequency greatly, up to 20,000 Hz.. And with flickering at 20,000 flashes per second, there is little risk from flicker because our visual system cannot see or sense anything that flashes that fast.

In fact, we will only be able to see flicker below 50-60Hz. And studies show that only unseen flicker up to 160Hz can affect us physiologically. So faster is better.

This battle between the two types of ballasts has already been won. Electronic ballasts have become smaller, more energy efficient, easier to implement and cost effective.

Magnetic ballasts are becoming a relic of the past, but can still be found in many old buildings and even homes.

Magnetic Ballast



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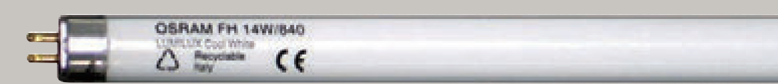
Electronic Ballast

Fluorescent Lamp



Never Knew Why

As mentioned, problems from flicker have been around since the introduction of Fluorescent Lights into work place (since the 1950s).

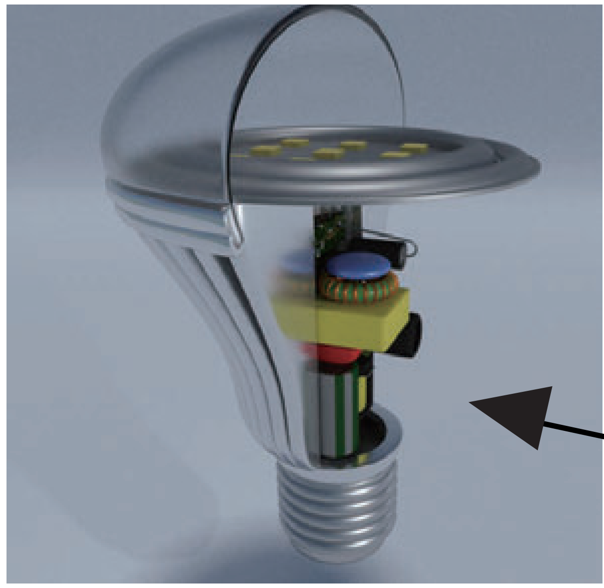
That might be the reason why my friend, as a child, some 50 years ago, experienced those headaches in classrooms.

LED lights and Flicker - The battle just began

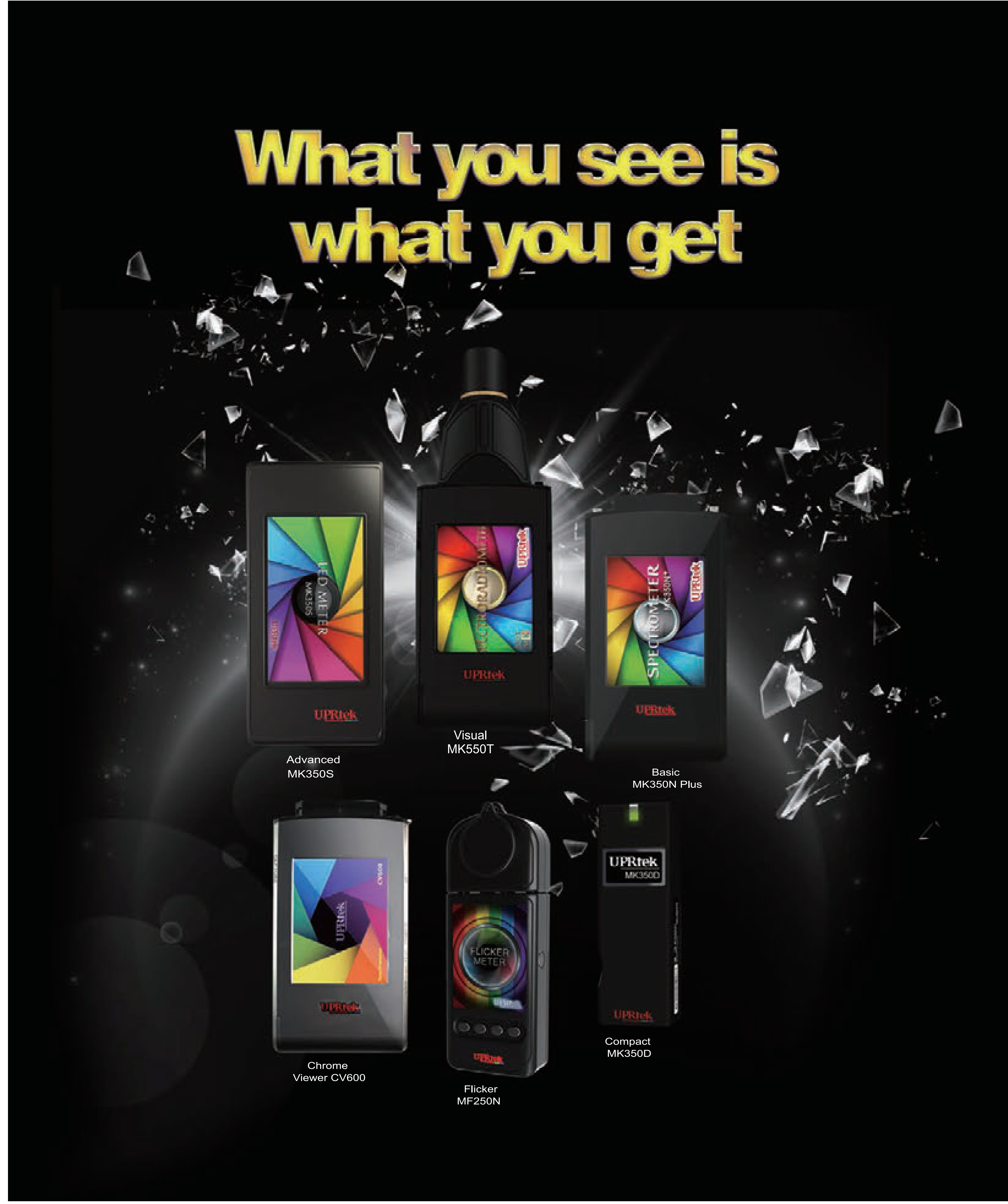
The approach to mitigate flicker in LED lights is slightly different. LEDs are equipped with a "**Driver**" that serves to supply the light with a constant flow of power, smoothing out the unwanted fluctuations from the AC power line.

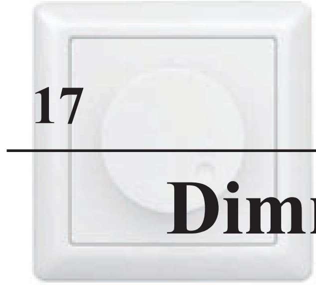
Remember flashlights, DC continuous flow and flicker-less light? Drivers in LEDs take the AC current and transform it into a DC current before reaching LED light itself, thus eliminating flicker. However, high quality drivers are sophisticated devices that are expensive to produce and drive up the price of LEDs.

There are less sophisticated LED bulbs in the market with lower quality drivers that go for a much lower price, sometimes half the price of quality bulbs. These bulbs will have a higher potential for flicker.



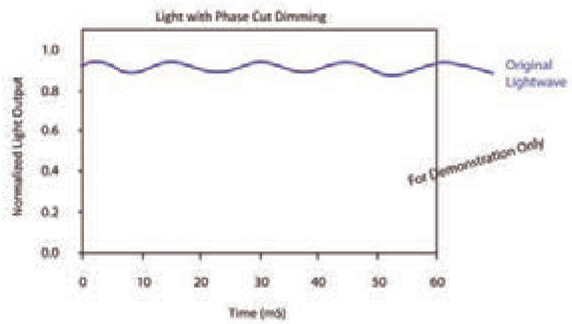
Driver



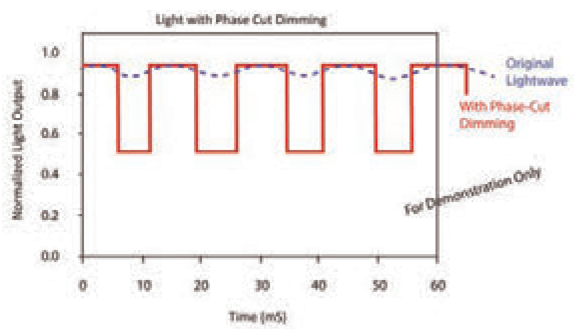


Dimmers and Flicker

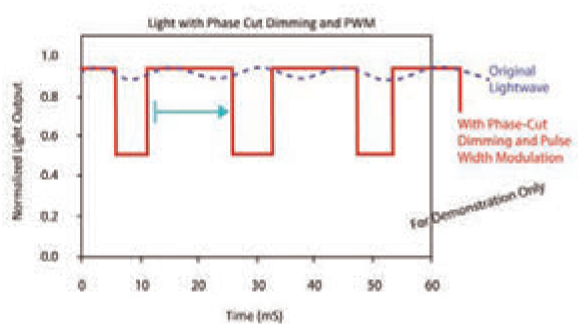
The process of dimming is actually a bit of a reverse process from what we've seen. Initially an LED driver will transform the wall socket AC to DC and send it along to the LED so it may illuminate without flicker.



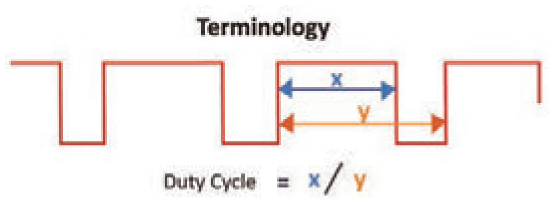
If you dim the light, the driver will insert breaks into the light flow using a technique called **Phase Cut.** The small cuts reduce the amount of total light output (dimmer) - the cuts are too short in duration for our eyes to notice. However, the resulting light wave pattern will become similar to the waves we've seen before - and of course by doing this, you have reintroduced the aspect of flicker.

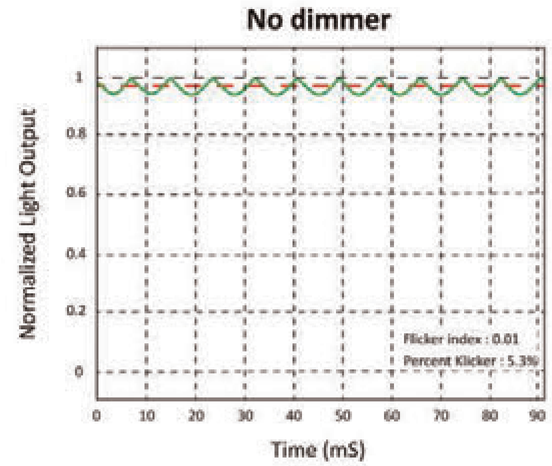


Dimmers (or actually the drivers) can remedy the flicker in the previous example using **PWM or Pulse Width Modulation**. It increases the amount of high intensity light in the light wave, increasing the proportion of high intensity to low intensity to favor less flicker.

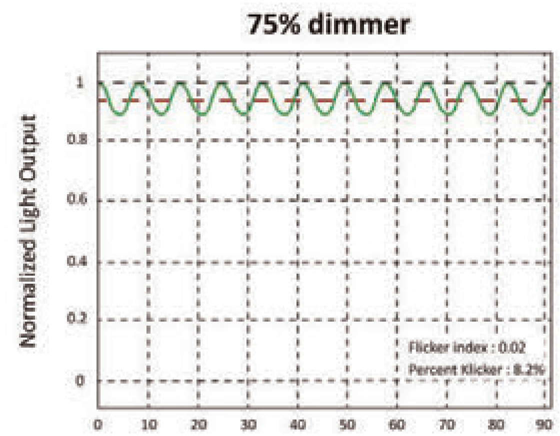


There is a special term used to refer to the width of the high intensity phase. It is called the **Duty Cycle** and simply is a ratio of the time in the high intensity phase divided by the entire time of one cycle. In our case a larger duty cycle will result in more high intensity light and less flicker.



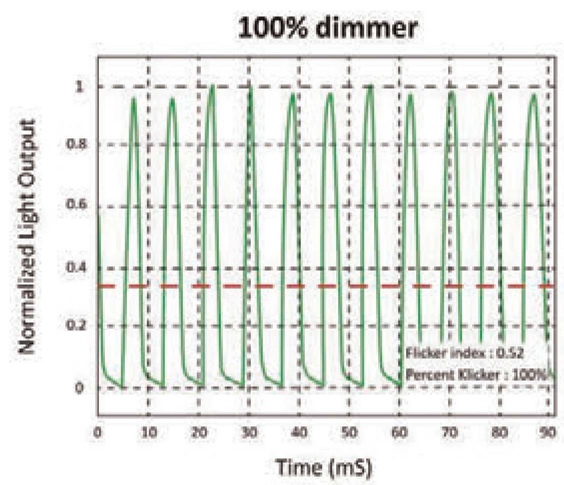


The light wave to the left show a light that is not dimmed.



The next wave (left) show how actual light waves might look when dimmed.
Notice how the Phase-cuts get progressively deeper with more dimming, which will favor more Flicker.

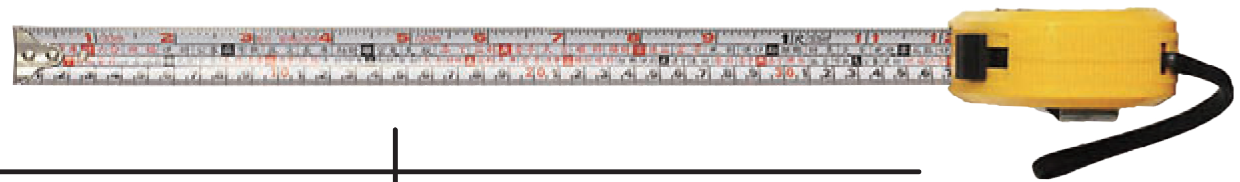
Again, it is a well designed driver that can mitigate dimmer derived flicker by increasing the Duty Cycle or by increasing the frequency to the point flicker is beyond what our eyes can see (beyond 50Hz-60Hz) and what our retinas can sense (beyond 160Hz).



Dimmers must also maintain the color of the light, which can change with the light intensity.
So "dimming" is a challenging a proposition, and it takes a good driver to maintain color quality and flicker-less performance.

What is the unit of measure that will ultimately determine the severity of flicker?

The $1 million question



The Good Work

There have been plenty of studies on light flicker and its consequences, and many standards organizations are working diligently to define the metrics and thresholds for unacceptable flicker severity.

CENELEC

IEC

ENERGY STAR

NEMA

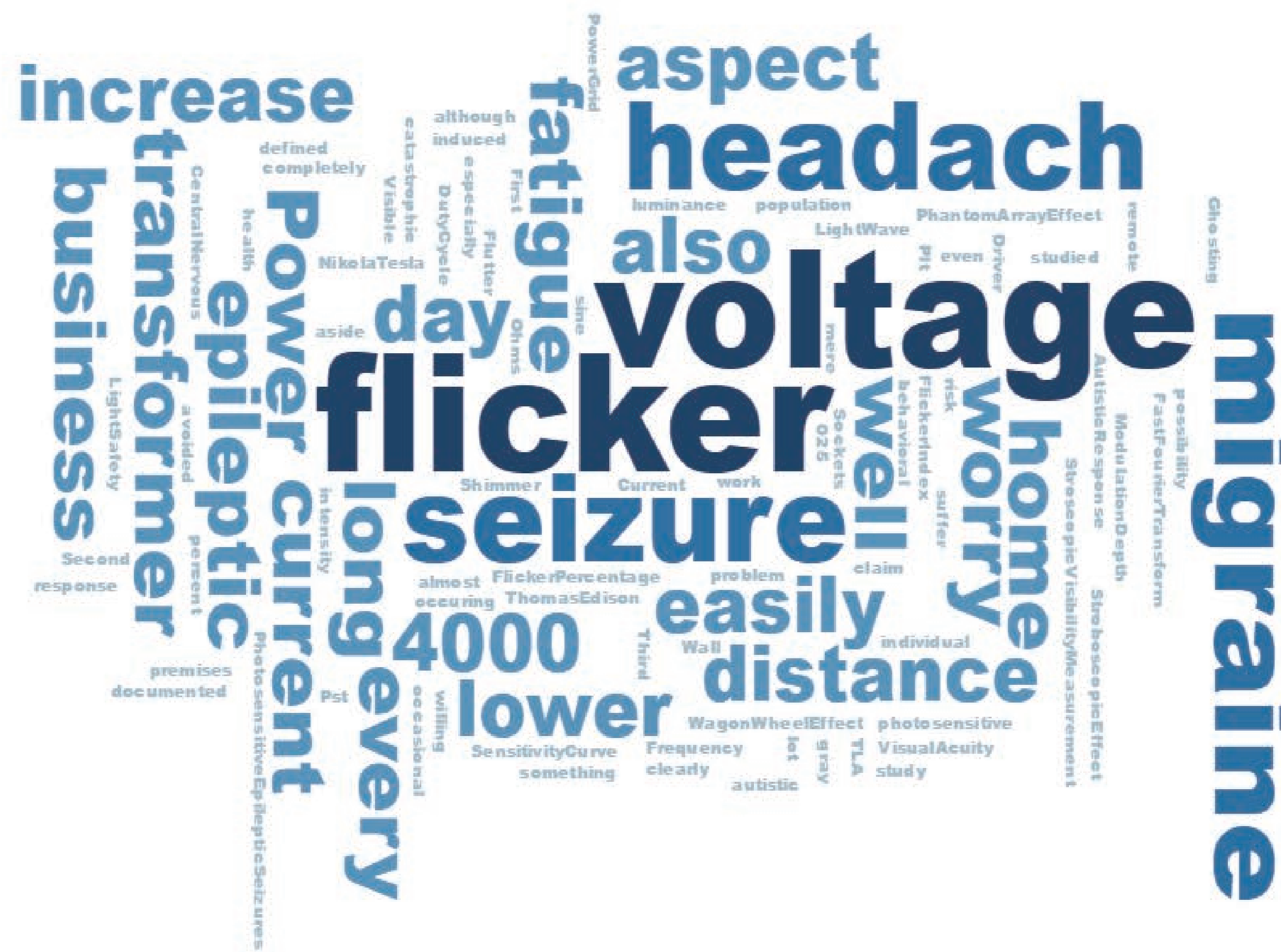
IEEE

cie

Best game in town?

Truth be told (at the time of this writing), a pervasive, unified, well defined metric or metrics for defining unacceptable levels of flicker have not been established as a standard.

And this is because of the myriad of factors, situations, permutations and the largest variable or them all, the human body, in all it's various incarnations. However, flicker metrics do exist, and though a single metric may not be 100% water tight, together, they just might be the best game in town.



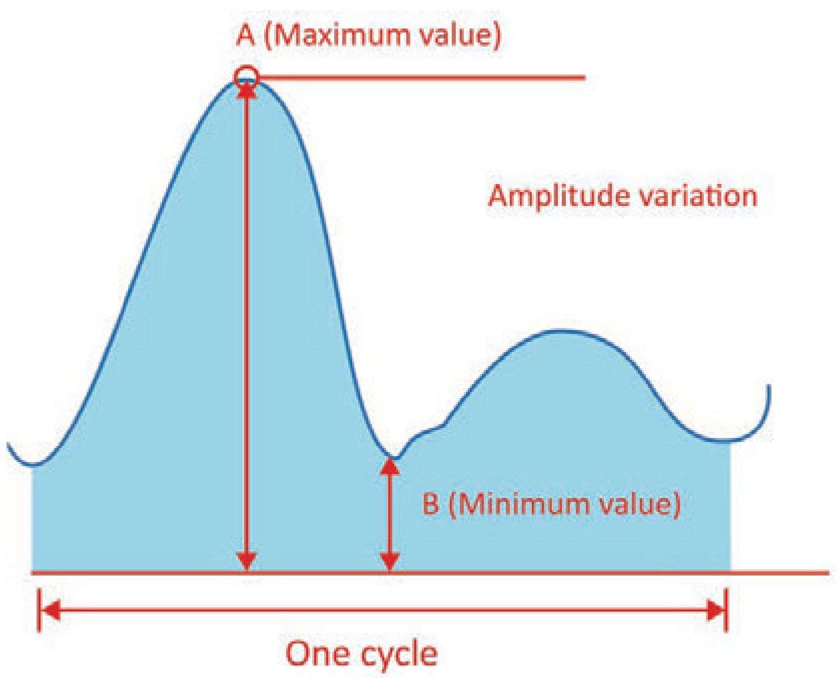
First Flicker Metrics

Percent Flicker

In the early 1980s, some of the very first flicker metrics could be seen in literature from the IESNA (Illuminating Engineering Society of North America - IESNA Handbook Reference Volume 1981).

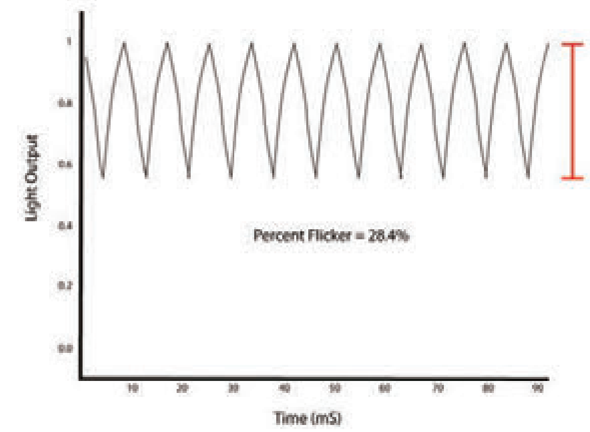
The first metric was called the Percentage Flicker and is relatively easy to understand and calculate. You simply compare the highest intensity and the lowest intensity points on a single cycle of a light wave to yield a percentage.

Percent Flicker = 100* (A-B) / (A+B)

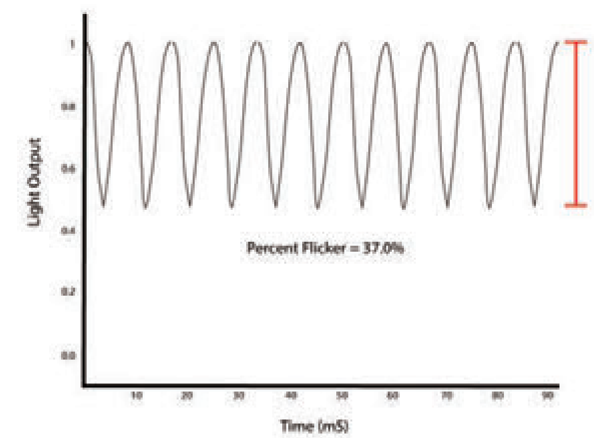


Basically, if the difference between the high intensity point and low intensity point is large, your flicker will be more severe. This is what the Percent Flicker is calculating - the severity of flicker in numbers. The higher the Percent Flicker, the higher the discrepancy between hi and low intensity light and the higher the flicker severity.

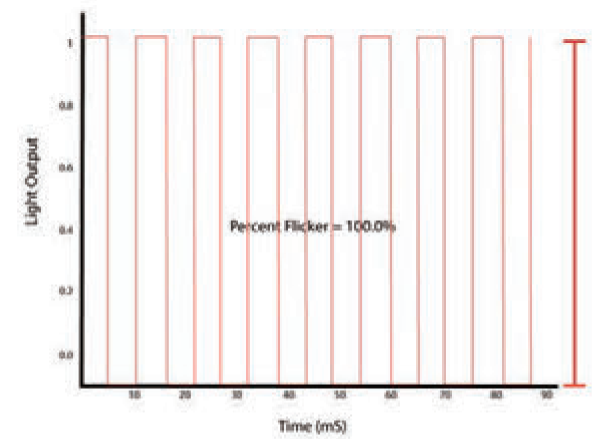
In the first example (right), the Percent Flicker is calculated at 28.4%.



In the second example, the wave is deeper, showing a wider discrepancy between the highest and lowest points, and thus yielding a higher Percent Flicker at 37.0% and opportunity for Flicker..



Finally, the last example shows a wave that reaches the bottom at intensity zero, which means at these intervals, there is a complete break in light. In these cases, the Percent Flicker is most severe at 100%.



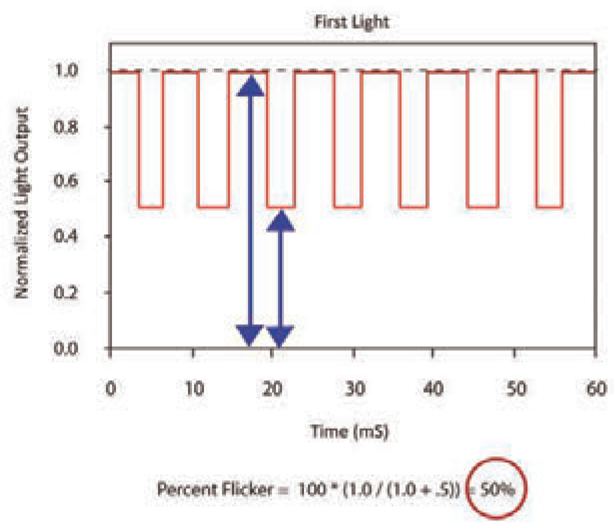
Terminology

Percent Flicker is sometimes referred to as **Modulation Depth**

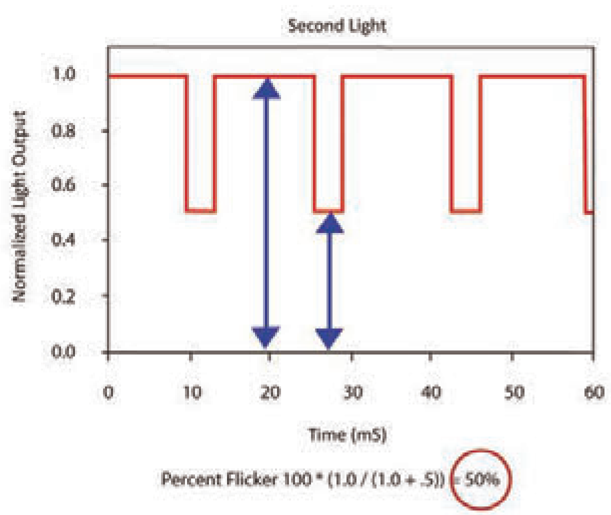
Flicker Index

Although the Percent Flicker is easy to calculate and understand, it has its drawbacks. Particularly, it is only one dimensional, comparing height only . It also fails to address time. In other words, how much time the high intensity light is illuminating vs the amount of time in low intensity light is illuminating.

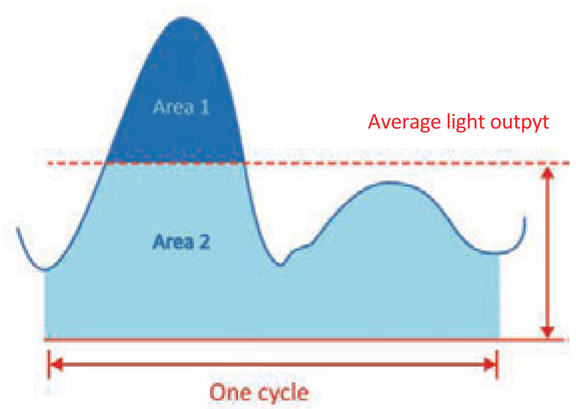
Look at the first example one the right. It has a Percent Flicker of 50%.



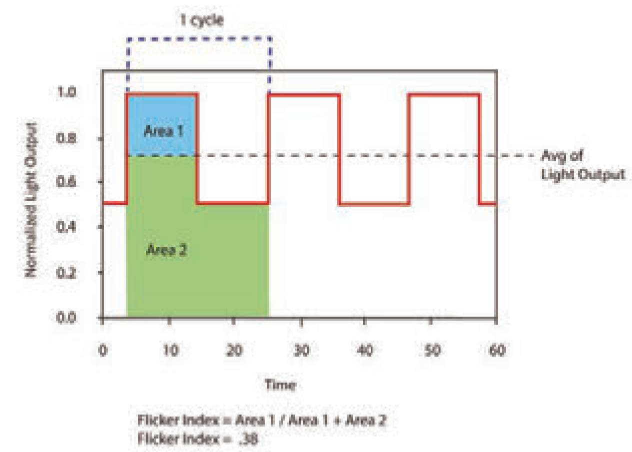
Now look at the second example (right) , where the light wave is noticeably different than the first and yet the Percent Flicker shows the same value (50%). Therein lies the problem. The Percent Flicker does not take into account the horizontal aspect of the graph - in effect,time.



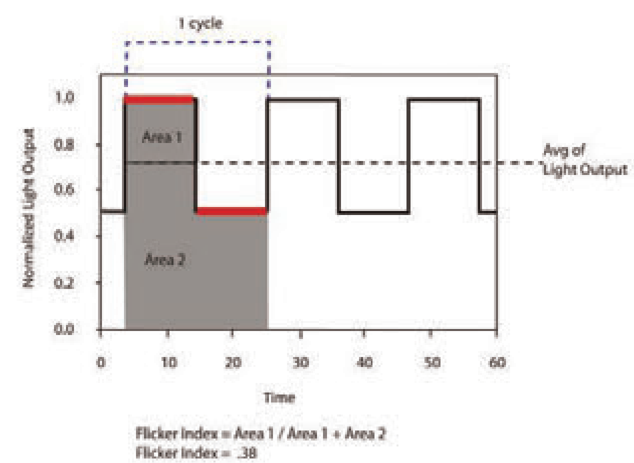
The next metric is called the **Flicker Index** and it improves on the Percent Flicker by taking into account what is happening over one cycle. At first, the metric might seem a little confusing as it is measuring and comparing "Areas" under the light wave. It is basically measuring the intensity of light over time (x and y), so might think of the area like a quantity of light. Simply said, it is comparing the quantity of light at high intensity against the quantity of light at low intensity over one cycle (but the details are a little more difficult)



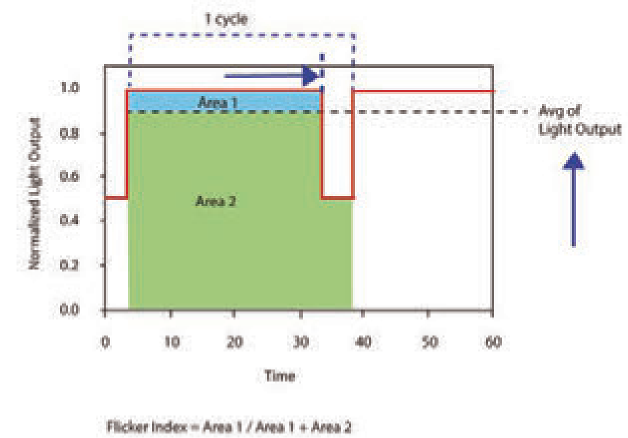
$$\text{Flicker index} = \frac{\text{Area 1}}{\text{Area 1 + Area 2}}$$



Let 's start with an easier example (left) with square waves, whose areas are easier to comprehend (Area = L x W). Area 1 in the example represents the difference between the amount of high intensity light over low intensity light. Area 2 represents the residual amount of light shared by both high and low intensity light. To calculate the Flicker index would be Area 1/Area 1 + Area2. It's basically a percentage like Percent Flicker but you don't multiply by 100.



But what is that curious line demarcating high and low, called "Avg. of Light Output"? That would be the average of all the points in the two red lines shown to the left. This line demarcates the area that defines the difference in high and low intensity and will end up somewhere between the two extremes.



In the third example (left), you can see what happens when we extend the time the light is at highest intensity (increase Duty Cycle).

When this area becomes wider, the "Average of Light Output" line gradually moves up (see compared to first example), Area 1 decreases and the Flicker Index also decreases.

Ergo, increasing the width of the high intensity portion (Duty Cycle), essentially reduces the Flicker.

Some Dimmers and LED drivers do this purposely to reduce flicker, a method called Pulse Width Modulation or PWM, which we talked about earlier.

So how do you measure for Flicker?

Analyzing a light for Flicker is similar to what a doctor does when he/she examines you when you're not feeling well. At first the doctor will look at your countenance, check your pulse, listen to your heart, ask you to cough, using all the tools in his black bag to properly make a diagnosis.

You'll also find that searching for Flicker problems is much the same, and you'll also need the proper tools and a full Flicker Meter is a good place to start. Let's begin the examination.

1 Check Light Wave

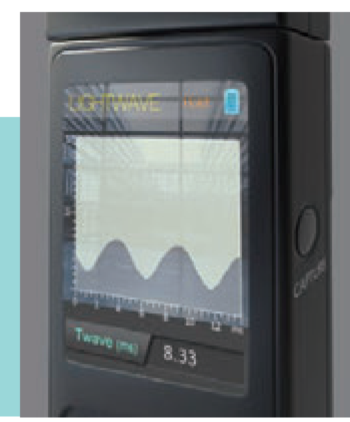
When you first examine a light with a flicker meter, one of the first things you can do is get a quick visual assessment by looking at the light wave.

At a glance, a light wave can already give you some quick information before you start looking at any numbers.

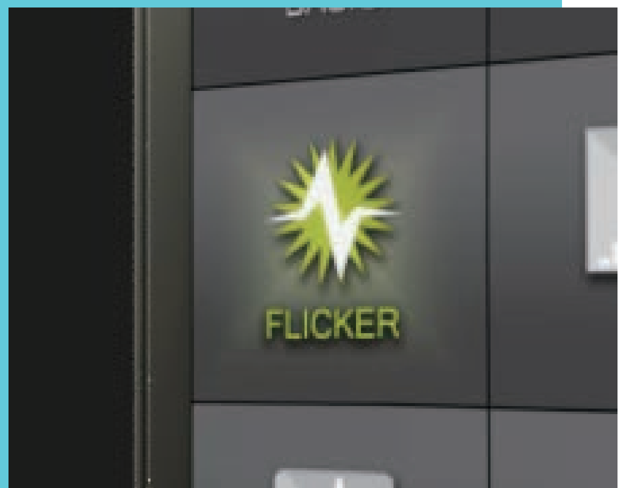
A relatively smooth, almost straight line can immediately tell you that there is little flicker. This can indicate LEDs with good drivers, Fluorescent Lights with Electronic Ballasts, or just simply Incandescent Lights.

However, you may also see sharp cornered waves as we discussed earlier. As mentioned, these waves can sometimes be seen with LEDs with low quality drivers, registering higher flicker because of the sharp drop off in light intensity.

If the lowest points on the wave reach all the way to the bottom (zero intensity), it means there are complete light breaks, which is another factor favoring Flicker.

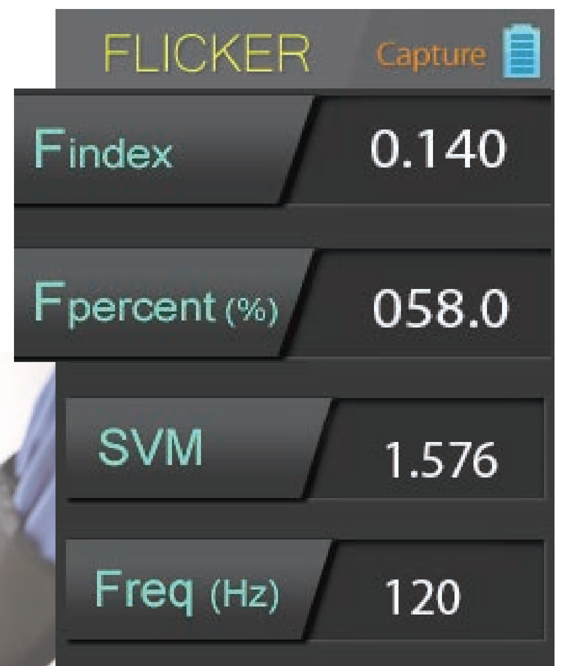


There are still a lot of buildings with older fluorescent lights that you may want to check for Flicker. This is a light reading from a fluorescent tube light that was installed over 10 years ago. My guess is that it has an older magnetic ballast tube because it's suggesting a significant flicker.



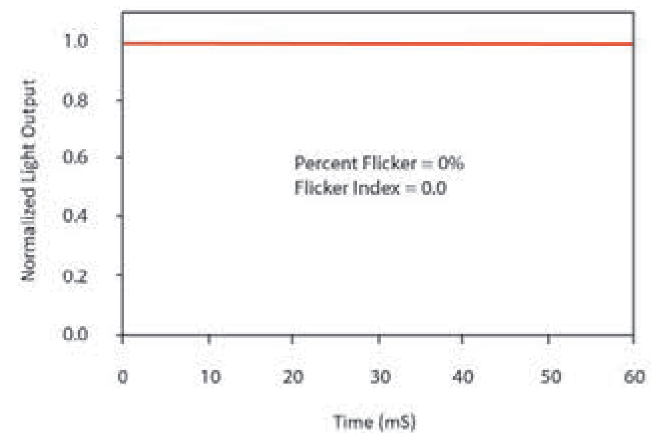
Check the numbers

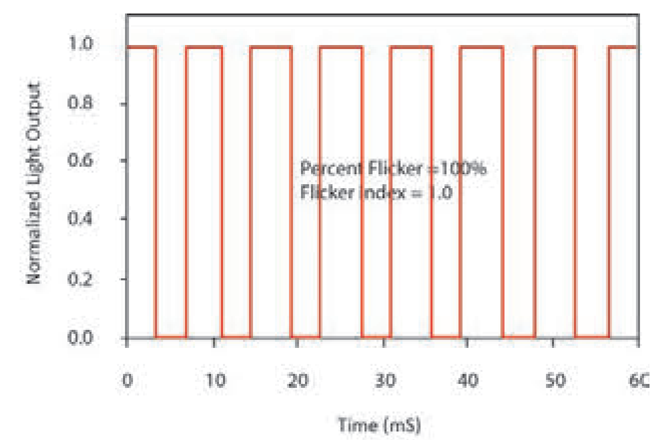
So we've determined in our last example that we have a light that's exhibiting possible adverse flicker. Now it's time to check the numbers.



Understanding the Extremes

First of all, you must understand that there are lights (LED, fluorescent, Incandescent) that manage flicker almost completely and you will find that their Percent Flicker and Flicker Index are both very close to zero, if not at Zero. You also know that the maximum Percent Flicker is 100% and the maximum Flicker Index is 1.00 (worst cases). Therefore you know where the extremes are and you can now see where your light numbers stand.





If you are lucky, the numbers will lie close to these extremes, which makes your diagnosis much easier – either you have a flicker problem (Percent Flicker 99%) or you don't (Percent Flicker 0.1%).

But if your numbers fall somewhere in the middle, the answer to your flicker problem becomes more troublesome – where do you draw the line? Because Percent Flicker is one dimensional and Flicker Index only considers one cycle, you can say they are ultimately deficient as flicker metrics. But there is another important item that factors another dimension of time.

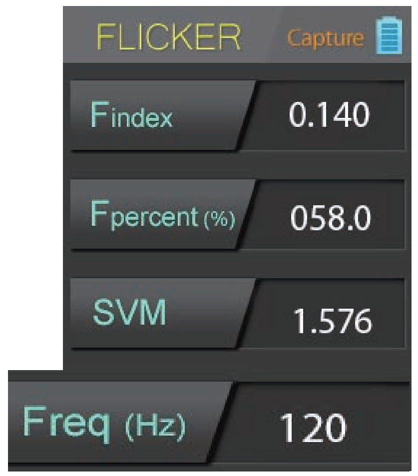
3

Check the Frequency

As we mentioned earlier in the article, our eyes can only visually perceive flicker up to 50-60 Hz (50-60 flashes per second). However, flicker frequency above that (non-visible Flicker) can still affect us physiologically up to 160 Hz (160 Flashes per second).

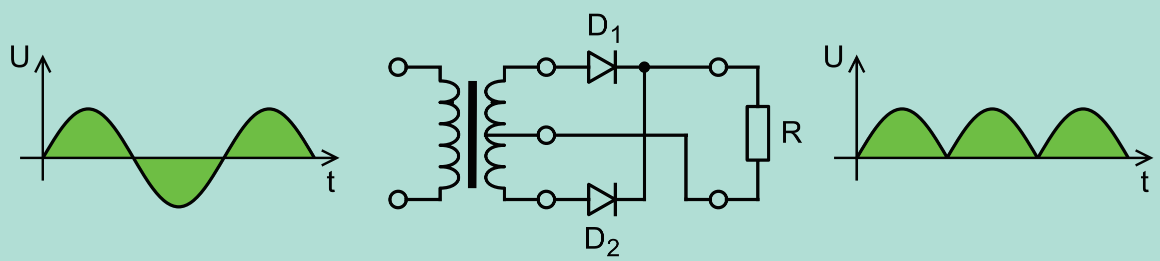
This all means that if you find that your Frequency well exceeds 160 Hz, you don't really have to mind the Percent Flicker and the Flicker Index. Faster is better.

In short, the Frequency also plays a large part in determining Flicker. To complicate matters, there is also a correlation between frequencies and other factors, meaning Flicker is determined by the interplay between frequency, light wave height, duty cycle etc.



Why is my frequency 120Hz?

If the AC frequency in the mains is 60Hz, why does my meter always read 120Hz? Within your bulb or Luminaire there is a process to convert AC to DC (as mentioned earlier) to smooth out the fluctuations in AC. This is a process called "rectification" and it is done by taking the backward aspect of the alternating current and polarizing it to the forward as below (AC to DC). In doing so, the frequency has been doubled to 120 Hz and the flicker has been much improved with a lower Percent Flicker and faster frequency (light wave on the right).

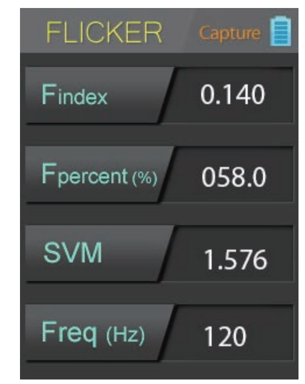


4

Make the Diagnosis

Let's return to our example. Do we or don't we have a flicker problem? Our light wave certainly exhibits flicker characteristics, our Percent Flicker, Flicker Index are both elevated, and our frequency is in the range of what are eyes can sense (but not see).

Ultimately, where do you draw the line to determine whether your levels of flicker are severe or not? Is it serious enough to affect someone susceptible to migraines? Where's the line for eye fatigue? Where's the line for epileptic seizures? Where's the line for people under 60 (young people more susceptible to flicker)?



In 2015, the folks at IEEE were good enough to come up with a simple, reasonable standard using the Percent Flicker and Frequency (IEEE Std 1789-2015).

In this standard they recommend the following:

1) Calculate Frequency * .08 (120 * .08 = 9.6)
2) Compare Percent Flicker (58.0) against the calculated number (9.6)

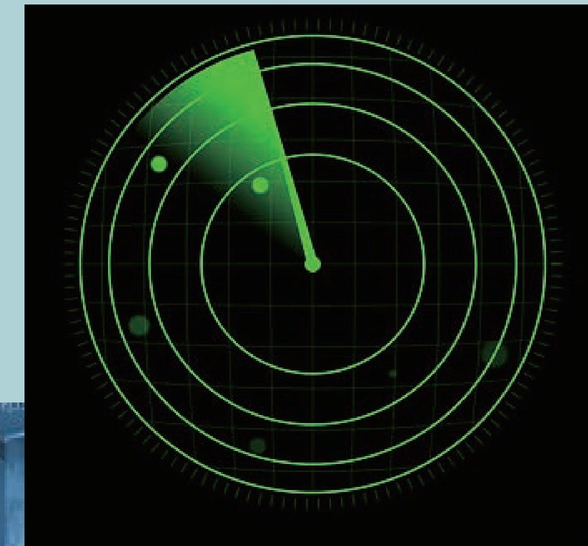
If your Percent Flicker is larger than the calculated number in #1 (and it is for us 58.0 > 9.6), you have a Flicker problem with your lights and you need to take action (replace or buy new).

But what if? (high blood pressure)

But what if you just bought and installed 20 LED light bulbs and your calculations showed as below.
14 > 120 * .08 = 9.6
Our Percent Flicker (14) is over the 9.6 limit, but by only a mere than 5 percentage points, much better than the 50 point spread in the previous example. Do I change my bulbs? No one at this time can answer that question with absolute clarity - once you get over the limit you are entering gray areas. It's kind of like High Blood Pressure - the cutoff for high blood pressure is 140/90; but if your BP is 141/91, should you start taking medication? What if your BP is 139/89?

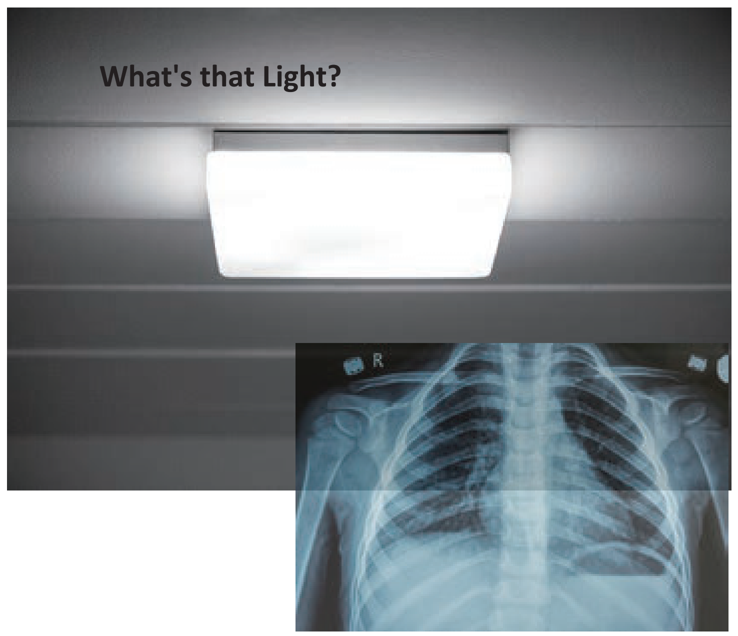
Real Time Point and Monitor

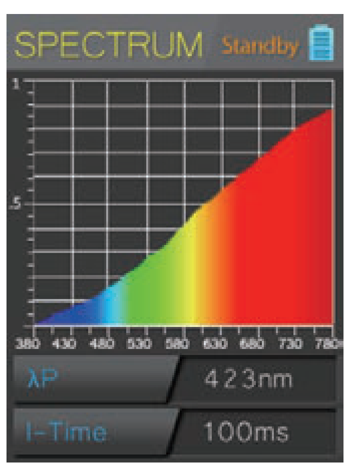
You have a factory with 200 fluorescent ceiling lights. You know that some of the lights will begin to flicker as they become older. One of handy features of a flicker monitor is not only it's portability, but it's ability to point and monitor in real time. This gives you the freedom to walk around and scan large areas for flickering lights. The MF250N has a head mount sensor that you can rotate 180 degrees to the front while, at the same time, monitoring the information on the screen panel in front of you. The Flicker Metric data, FFT graph, and Light wave all can monitor the changing data in real time you as move from area to area, without pressing any buttons.



What now?

You've determined that your light(s) are exhibiting flicker in a undesirable range , but how can you determine the type of light source (incandescent, fluorescent, LED) on a high ceiling with a cover on it.? A handy item on the Flicker meter would be the Spectrum display. With the Spectrum display you can identify the type of light under a cover so you can get an idea of what you need to fix.



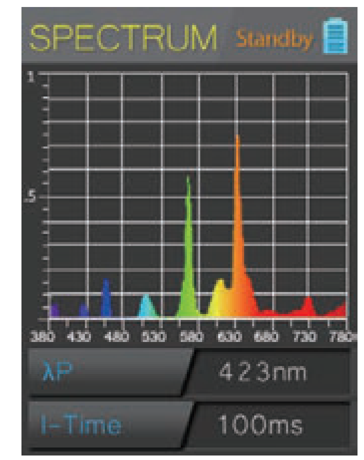


Incandescent lights usually do not exhibit flicker by itself, but may still may be influenced by dimmers and drain on the electrical current by high appliance equipment.

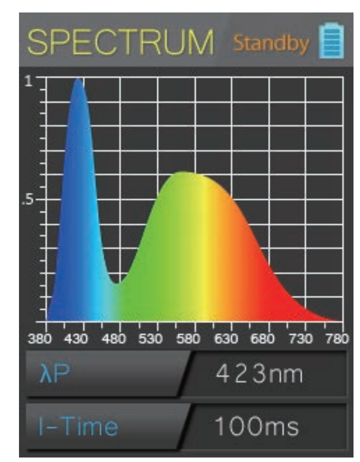
KMJ - GFDL - CC-SA-3.0

Sun Ladder - Creative Commons Attribution-Share Alike

Fluorescent light may exhibit flicker because of older style Magnetic Ballasts which need to be replaced with Electronic Ballasts. Or maybe the bulb is getting old and wearing out.



LED lights that flicker in modern environments usually mean low quality drivers that cannot handle AC fluctuations and/or dimming. These lights may exhibit both severe and moderate flicker.

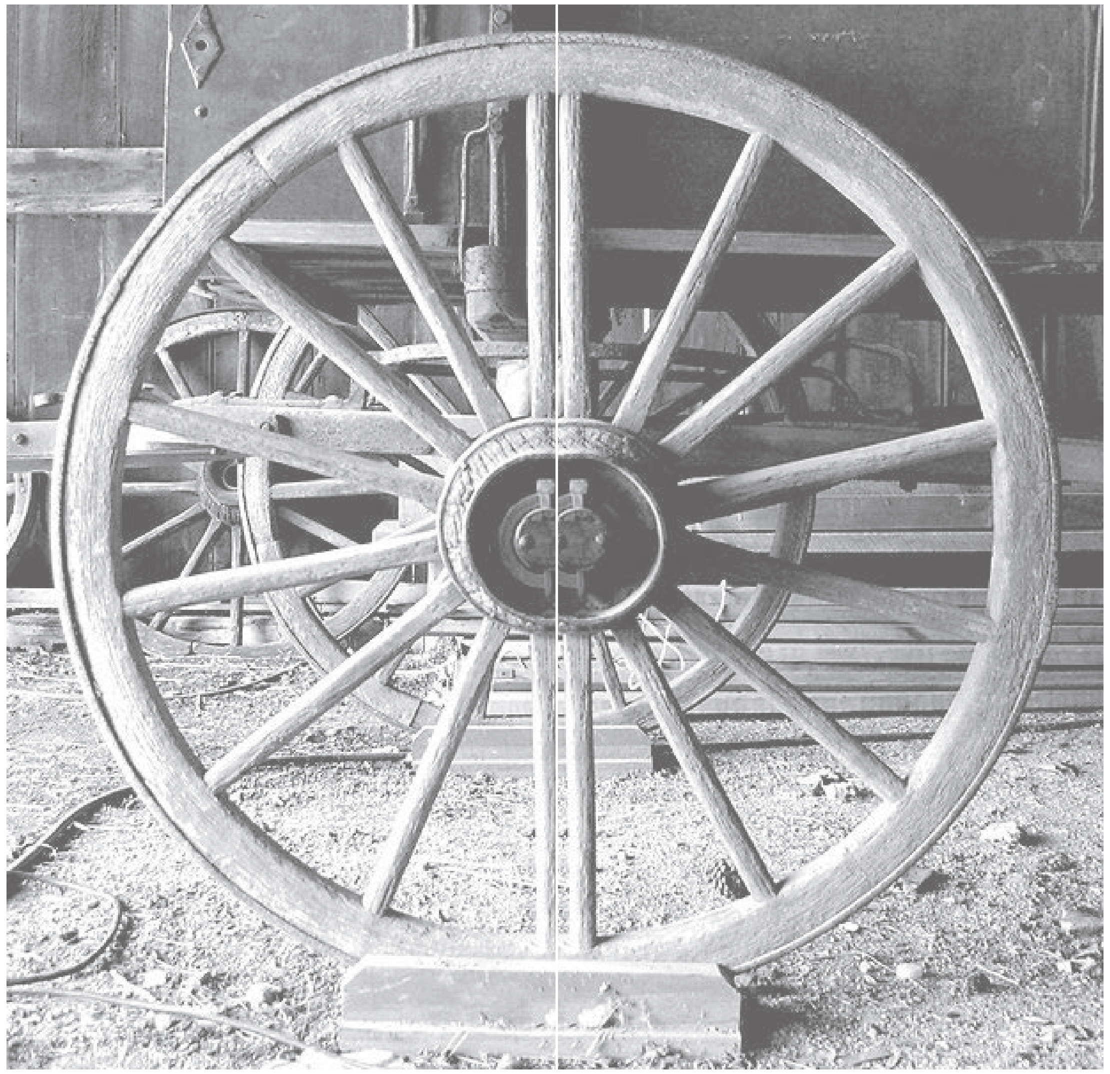


The Stroboscopic Effect

The Stroboscopic Effect, as mentioned earlier, is another category of TLA (Temporary Light Artifact). But contrary to the insidious nature of Flicker, Stroboscopic Effect can consequently bring shocking, catastrophic outcomes.

You may have seen a similar phenomenon in the movies. It's called the "wagon wheel effect" - as the wagon speeds along, the spokes of the wheel appear to stop or reverse directions. Helicopter blades in movies also exhibit this in movies. This is NOT categorized as a TLA, but the mechanisms are the same.
If you're still unclear, please see the video below - you can see the wagon wheel effect at the 10 second mark.

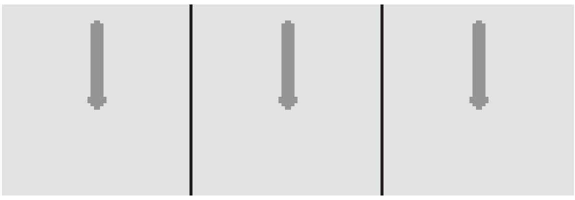
https://www.youtube.com/watch?v=6XwgbHjRo30



John Vetterli CC-SA 2.0

The "wagon wheel effect" is where the spokes of wheel appear to stop or even reverse directions. A video camera does not record a continuous stream of motion, but rapidly takes a series of pictures (or frames) at intervals of usually 24/30 frames per second (in older films) - when these frames are displayed rapidly one after the other, they appear as one continuous stream, like a flip page animation. But because the camera captures only 24/30 frames per second, it cannot capture all the fine degrees of spoke rotation around the center. So when the camera snaps consecutive frames, it sometimes captures the spokes at the same locations every time (even though it might be a different spoke). Please see the short clip below:

https://en.wikipedia.org/wiki/Stroboscopic_effect#/media/File:Strobe_2.gif



In this clip (above link), the box on the left represents what is happening in the real world (clock with second hand rotating). In the second box, you can imagine the camera snapping a frame every second, indicated by when the box background lights up white. But you'll notice that it takes a snapshot only when the

hand is at 12 o'clock. This means that when you string all the pictures together, the second hand will appear stationary in that single position.

Now imagine that camera is replaced by your eye and the white background flash indicates a one flash per second flickering light shining on the clock - what you will see is only the second-hand at the 12 o'clock position, because the flash of light is synced with the rotating second-hand as it lands on the 12 o'clock position.

But it's a little more complicated than that. You have to consider many factors before you get stroboscopic effect with flickering light (e.g. light intensity, duty cycle, modulation depth, frequency, how your eyes takes in information etc.).

And now here's the point of the story.

Let's imagine ourselves in a noisy factory. Their is a circular saw on one side of the table. Out of the corner of your eye, you reach for the ruler near the circular saw, as you do some busy work in front of you. It appears, in your peripheral vision, that the saw teeth are safely stationary, but in fact they are spinning at deadly speed. Get it? Shocking?

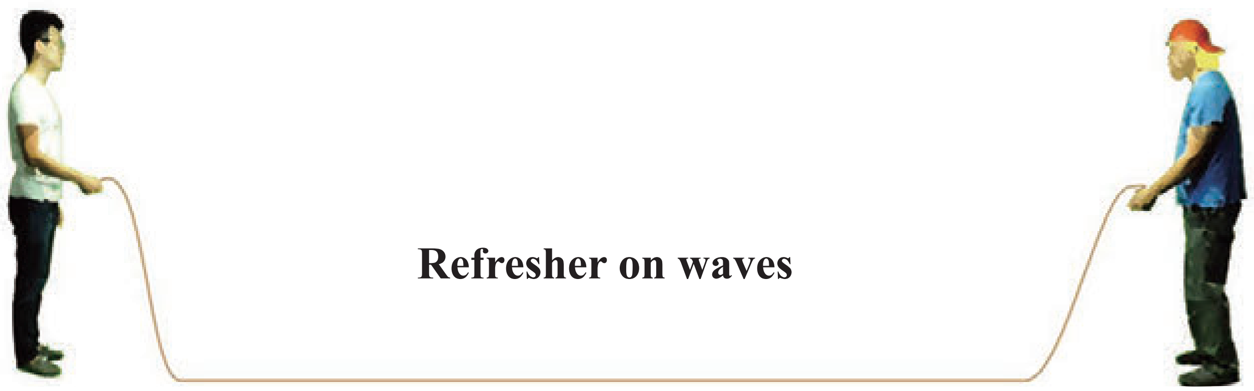
Basically, the saw teeth appear stationary because of flickering overhead factory lights (wagon wheel effect), and therefore your digits are in extreme danger.

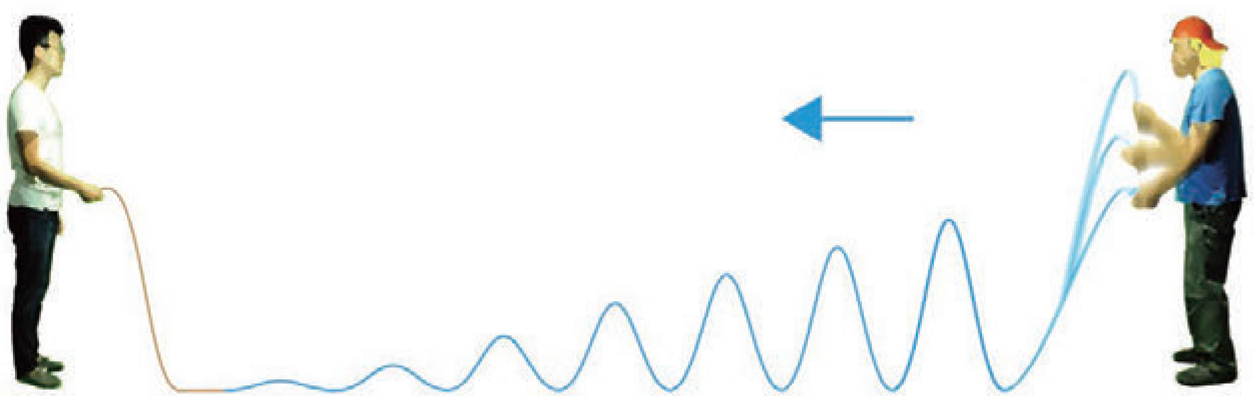
What in the world is Fast Fourier Transform (FFT)?

You may run across FFT browsing technical literature concerning Flicker. First of all, let it be known that FFT will be used mostly by academics and bulb maker engineers. If you've not heard of Fourier Transform, the term may seem a bit intimidating. Even if you look on Google or Wikipedia, you might be perplexed by what it is and how it relates to light bulbs.

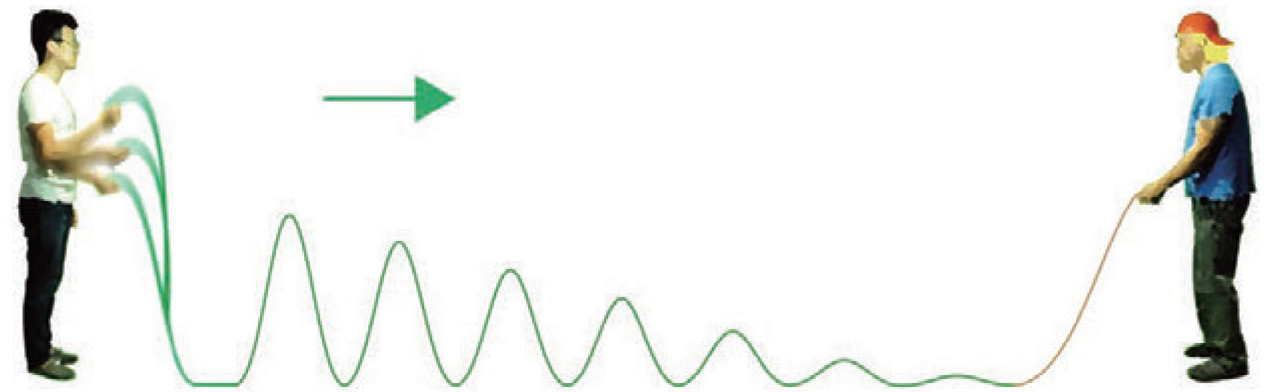
For this very simple explanation, a Fourier Transform is about analyzing and dissecting the characteristics of a wave - but not just light waves, any kind of waves; Sound waves, color waves, tidal wave etc. But before we venture further, let's review our knowledge of waves.

Refresher on waves

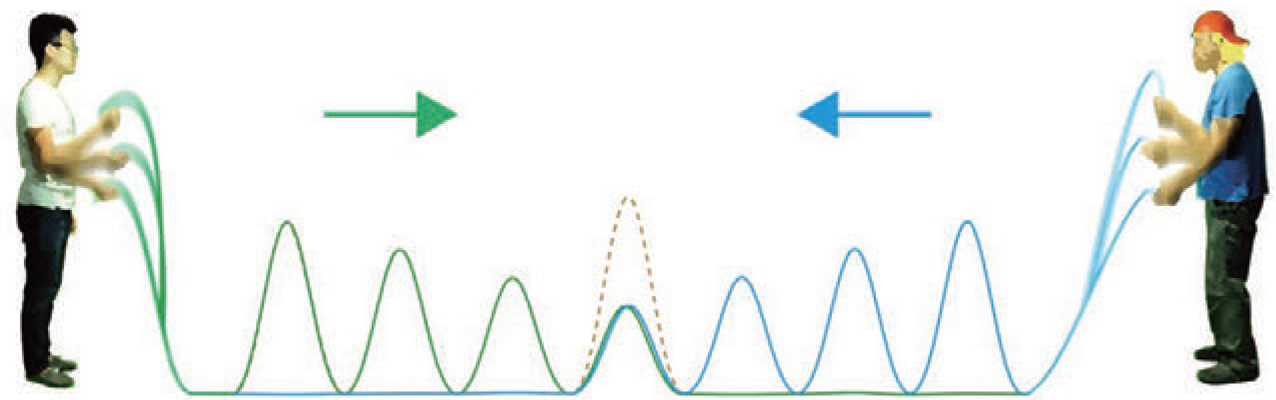




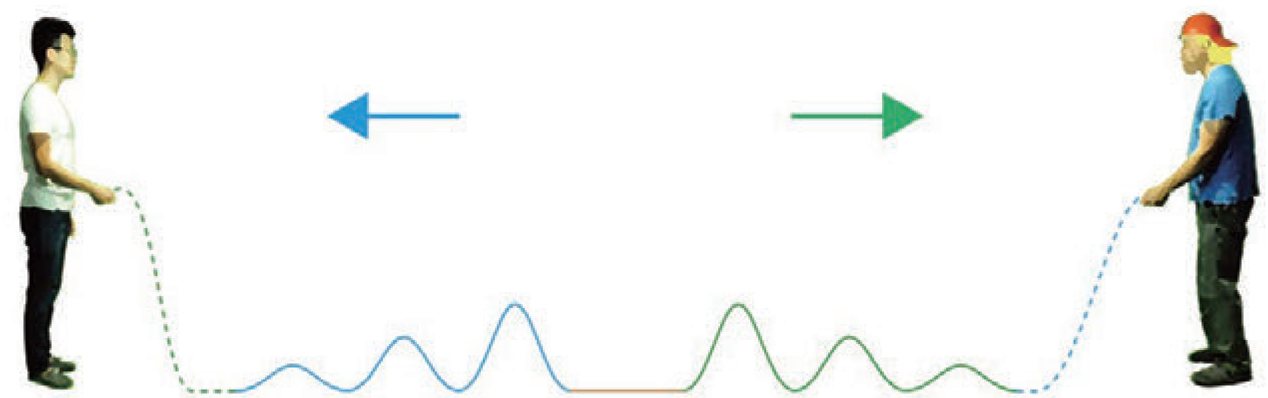
You can make a wave by jerking on the end of a rope. The wave traverses along the floor in a certain direction.



A similar wave can be made from the other side with the opposite direction.



Now start the waves from both ends. When the two waves meet in the middle, the waves are compounded into a larger wave which is the summation of the two waves.

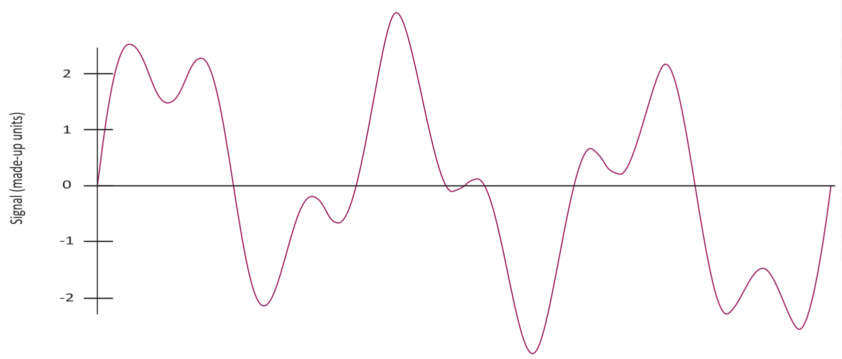


Once they pass each other, both waves return to their original direction, shape and momentum.

This is the amazing characteristic of waves, being that two separate waves can exist on a single medium, collide, interact and pass through each other and yet still come out the other side maintaining their own unique independent features.

FFT - So what does a Fourier Transform do?

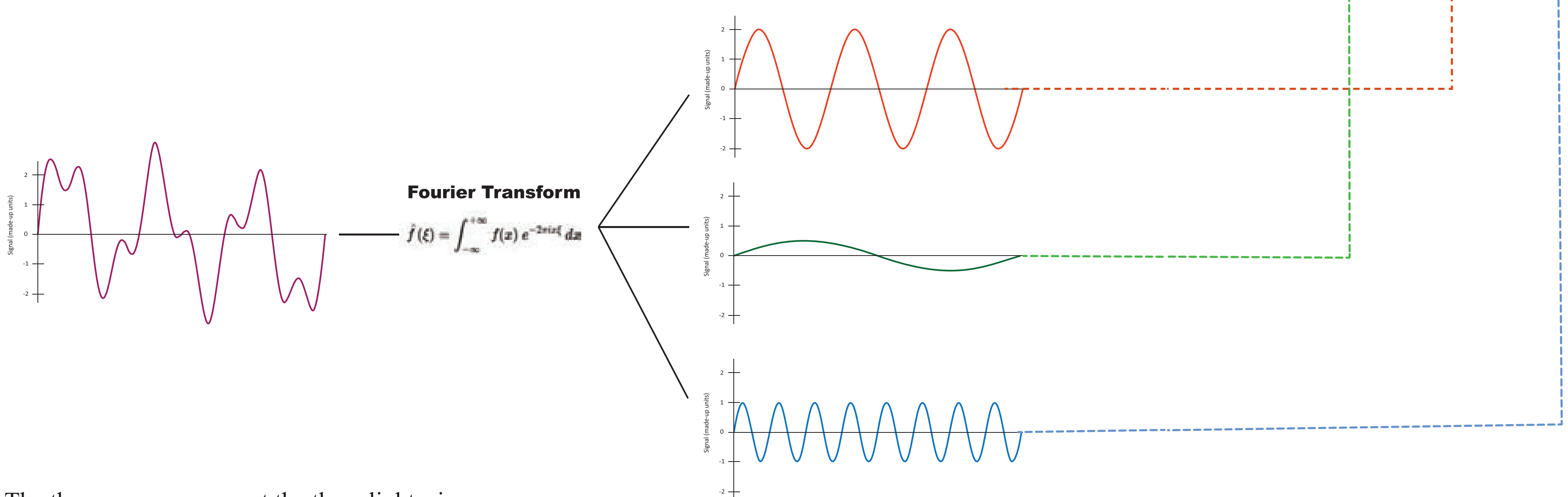
Back to Fourier Transform. Lets say we have three lights in a room. When you take a light reading, your meter will record a single wave. This single wave will contain a mixture of all three waves, because we learned that waves can exist at the same place and still be individual waves. When you look at the wave (below), you won't know where one wave begins and the other ends. And it's hard to see the characteristics of each individual wave.



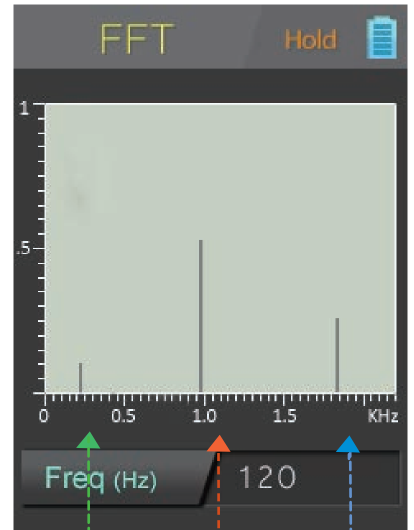
Joseph Fourier

1768 - 1830

As mentioned, a Fourier Transform is supposed to analyze the patterns in a complex wave and extract the component waves. And that is what it does in the example below, taking one complex wave and using the Fourier Transform formula to separate out the individual waves within.



The three waves represent the three lights in our room.



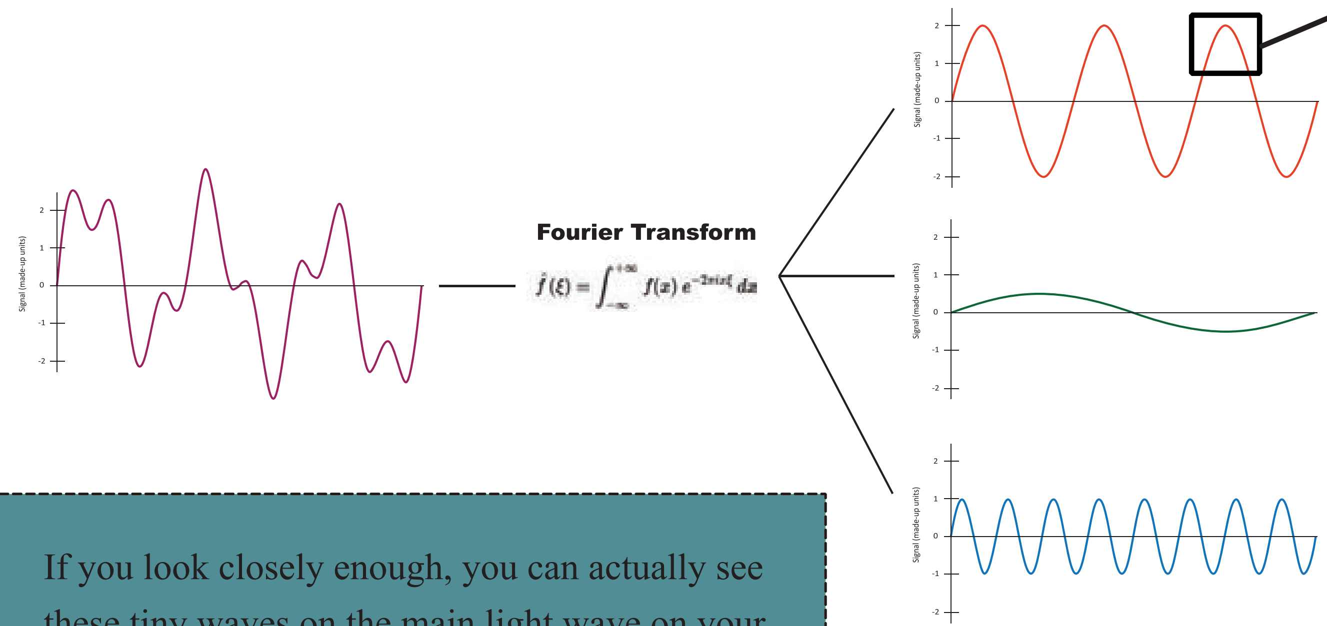
You might want to think of the FFT screen showing the 3 waves from the front, which shows the maximum intensity of each of the 3 waves (note, but NOT the difference between high and low intensity).

But there's more!

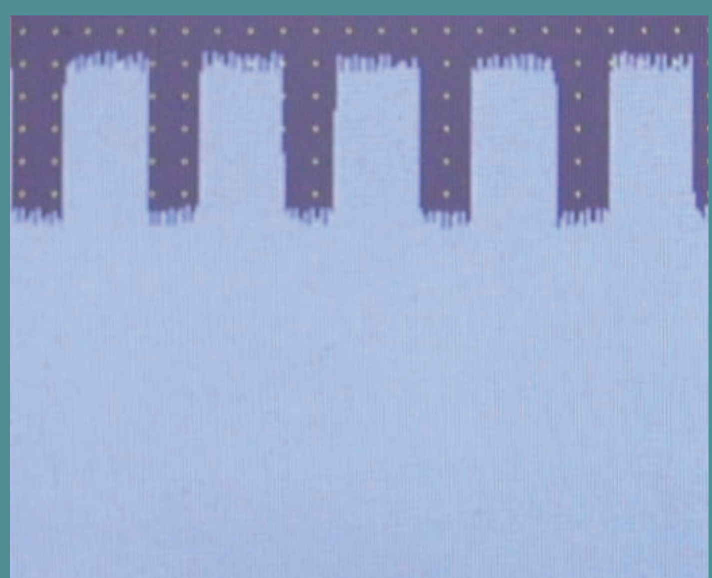
See this video about Fourier Transforms
https://www.youtube.com/watch?v=Qm84XIoTy0s

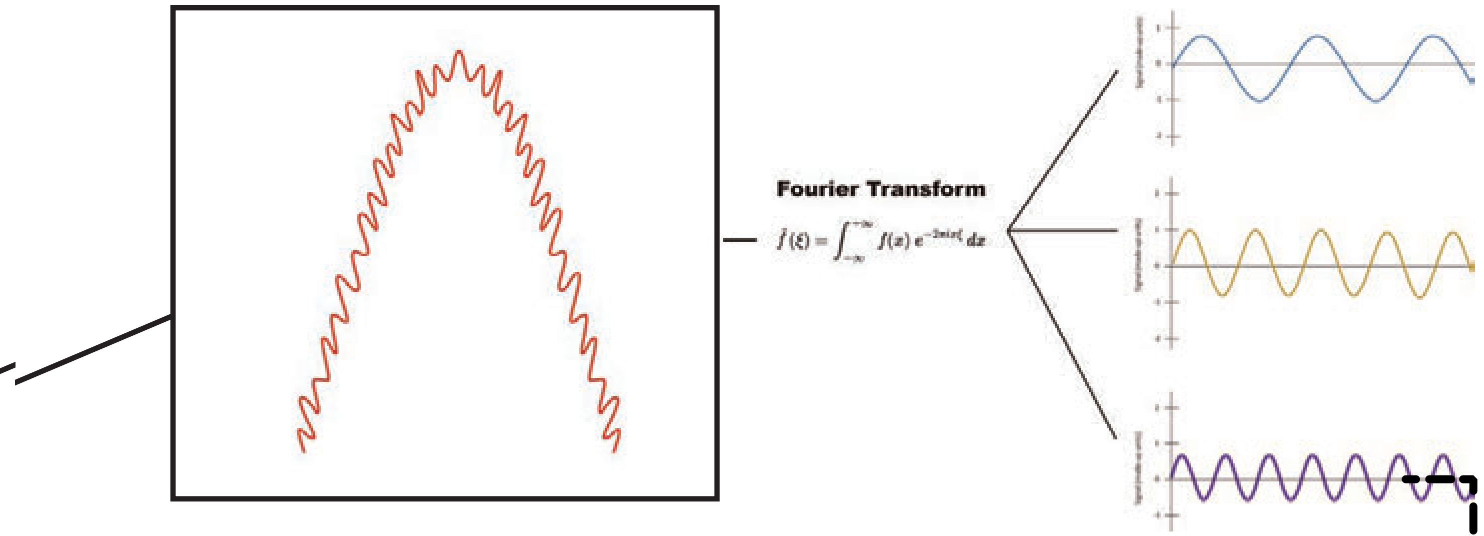
What a bulb engineer wants to see.

When you look at a wave close up, it will actually be made of many tiny waves, which we sometimes call "noise on the line", the subtle fluctuations in the power mains. These smaller waves are also identified and separated into their tiny wave components.

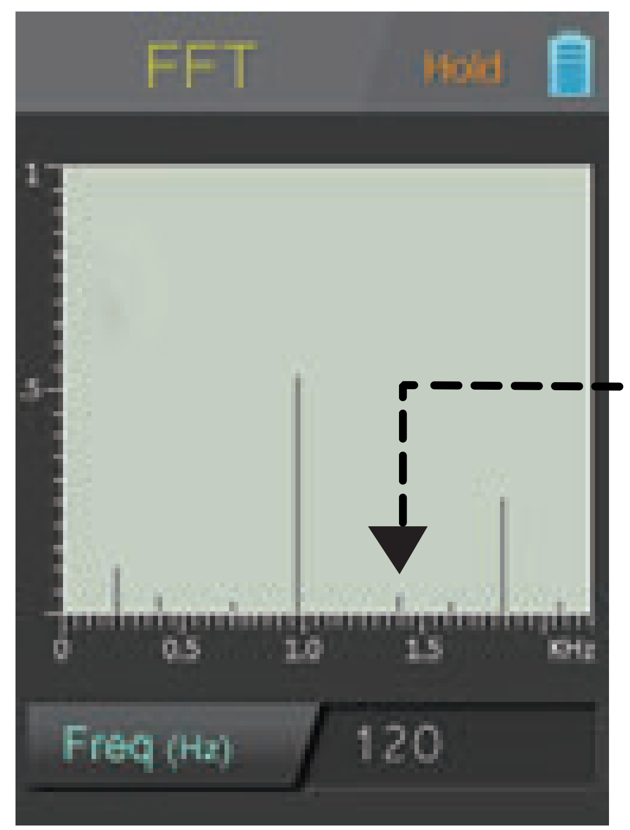


If you look closely enough, you can actually see these tiny waves on the main light wave on your flicker monitor.





These tiny waves can also pop up in the FFT graph as very tiny spikes. They come and go because noise on the line is very erratic. Even the main wave heights will change slightly because of slight inconsistencies in the power mains. These are the light wave details that lighting engineers are looking for when testing and experimenting with their products.



A New Approach

There's a new game in town. More organizations are beginning to realize that metrics like Percent Flicker, Flicker Index, Frequency are only numbers that do not address the real clinical problems. What is the relationship between Flicker and the Human Condition? There are organizations now making those connections by conducting clinical trial studies with real subjects to accumulate cause and effect data that links the numbers (duty cycle, frequency, modulation depth, percent flicker, flicker index etc.) with Flicker induced problems (headaches, fatigue, etc.).

IEEE is one of World's Largest Technical Professional Organizations

Pst, Plt

The metrics Pst and Plt are referred to as Flicker Short Term and Flicker Long Term respectively and were developed by IEEE (IEEE1453, IEC 6100-4-15 standard). The "P" stands for Flicker. The "st" stands for short term., "lt" stands for long term. These metrics are steeped in empirical clinical trials and are much more than a simple capture and must be run for 10 minutes and 2 hours respectively. In effect, the Pst and Plt addresses time much differently than Flicker Index (1 cycle) and Frequency (cyclic patterns) - it addresses fluctuations in the light wave over time. As we mentioned before ("What a bulb engineer wants to see"), the power mains is not as fluid as it may seem by looking at a light wave for a few seconds. There are subtle but significant changes and fluctuations that you can only capture over an extended period of time. It seems that Pst is beginning to gain acceptance from other important organizations and could be on course to be the industry standard for **bulb makers** in the future. However, for **field work** (e.g. spot checking for flicker in a factory of lights), the longer testing periods may prove impractical and the old standbys (Percent Flicker, Flicker Index, Frequency) still could prove valuable in this regard.

SVM

On the Stroboscopic front, Phillips has developed a metric to measure Stroboscopic Effect, called the SVM (Stroboscopic Visibility Measure). In the same light as Pst and Plt, SVM was developed integrating data from clinic trials using subjects observing different permutations of lighting factors (i.e. light intensity, modulation depth, duty cycle, frequency etc.).

Curiously, when measuring for SVM, you are not measuring moving or rotating objects looking for the "wagon wheel effect". You are just measuring the characteristics of only the light in

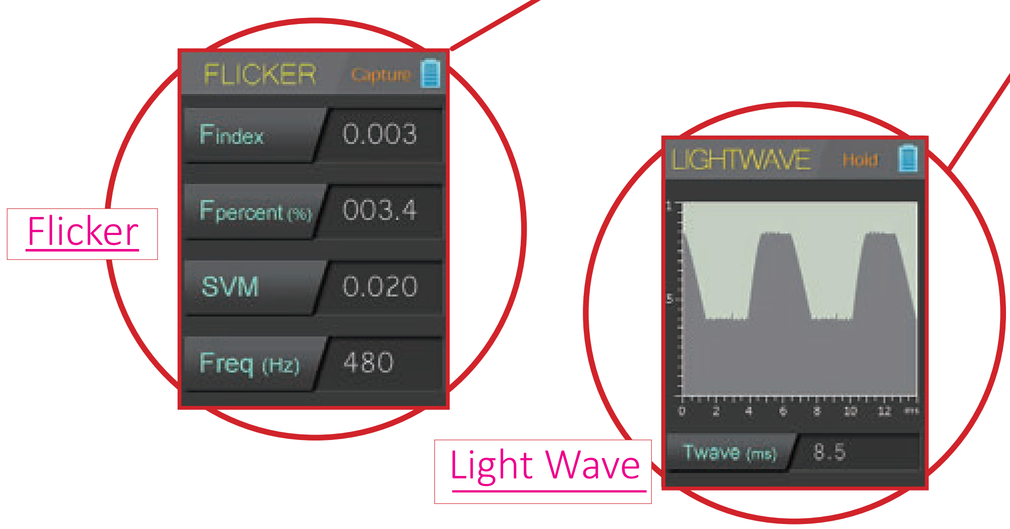
front of you. The light's characteristics, being combinations of frequency, light intensity, duty cycle, modulation depth etc, are matched against characteristics known to be conducive to Stroboscopic Phenomena, and are graded accordingly. The higher the SVM number, the more likely Stroboscopic effect will occur from the light in question.

CIE *(Commission Internationale de l'Eclairge)*

The CIE, historically and currently one of the most influential organizations concerning light and color, has endorsed both Pst and SVM as recommended measuring standards to address the issues surrounding flicker and stroboscopic effect (CIE TN 006:2016).

Conclusion

With the advent of LED technology, the Flicker issue is once again rearing it's ugly head from the days of flickering fluorescent lights. For most of the world, Flicker caused by lighting sources are still not highly regulated because of the complexities of the matter and uncertainties surrounding standards. Metrics like Percent Flicker and Flicker Index have long been around but only tell part of the story. Newer metrics like Pst and SVM show promise, and important organizations are beginning to endorse these clinically based measurement standards. Only time will tell if we can truly get a handle on Flicker. In a perfect future, LEDs hopefully will go the way of Fluorescent Lights with cost-effective Flicker-free LEDs. But as we've seen, even older Flickering Fluorescent lights will still linger in older buildings and classrooms for a long time to come. The Flicker issue is not always black and white, but the elimination of Flicker is. We have the tools to measure it and the technology to eliminate it.



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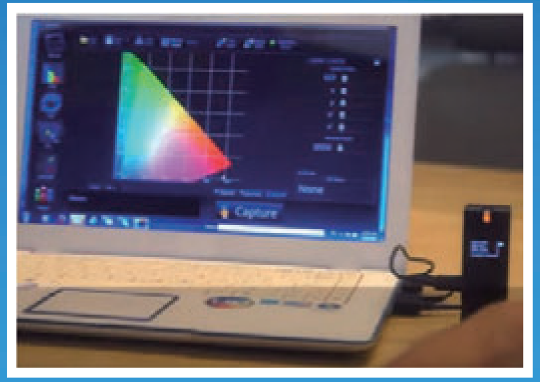

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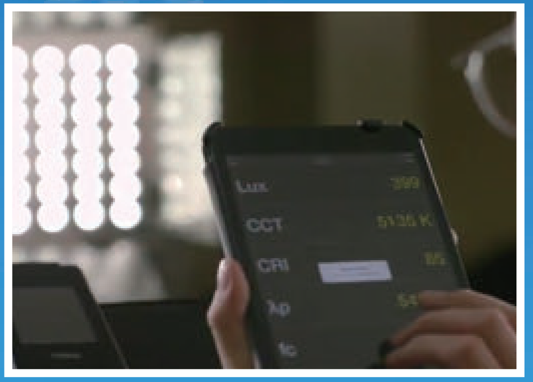

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