Electromagnetic Interference Detector

Title of the workshop: *Electromagnetic Interference Detector*
Target audience: *Entrepreneurs (18+ years old)*
Time planning: *Total 2-2.5 hour*
Estimated cost: *< 32 €*

Why Make It: This is a DIY electronics skill-builder with a practical application—reducing standby power, which adds as much as 10 percent to EU residential electric bills.

Step 1: Introduction to Physics

Picture A. Every day beauty

Have you ever wondered why soap bubble shine in various colors? Why oil on the road has all the colors even though oil itself is colorless? Or why butterflies have all these beautiful shining colors that changes when you look at butterfly at different angle? Well, now you can find out.

Picture B. Light as wave

First of all you have to know that white light consist of main seven colors: red, orange, yellow, green, blue, indigo and violet. We can beak light by using triangular prism (see Picture B) – since every color is a different length electromagnetics wave it breaks in different angles and that's why we can distinguish colors.

So if we want to found out why soap bubbles are changing colors, we have to find out some properties of waves.

Diffraction is a process that takes place when any wave on its way meets any obstacle. It is defined as the bending of light around the corners of an obstacle or aperture into the region of geometrical shadow of

the obstacle. These characteristic behaviors are exhibited when a wave encounters an obstacle or a slit that is comparable in size to its wavelength.
Diffraction can be used to separate different wavelengths of light using a diffraction grating. A diffraction grating can be a series of closely-spaced slits or a mirror with a series of small grooves. Diffraction gratings work because different wavelengths of light will constructively interfere at different angles. Diffraction gratings are used in many analytical chemistry tools, such as a spectrometer.
If we have single slit, the light waves reaching a given point on the screen each arrive from a different part of the slit, so their amplitudes must be added, and an **interference** pattern results. Interference is a phenomenon that occurs when one wave comes into contact with another wave and they interact. Interference can be either constructive or destructive. For two waves of equal amplitude interfering constructively, the resulting amplitude is twice as large as the amplitude of an individual wave. When interference is destructive, the intensity will decrease, sometimes to a point where it is completely destroyed.

In Picture C, consider pairs of points separated by a distance of half the slit width, such as (A, B) or (C, D). There exists a location on the screen for which waves coming from point C are out of phase with waves from point D by exactly one-half of a wavelength, so their amplitudes add to zero. The situation shown (n=1) in Picture C is for the first destructive minimum and occurs at two positions with angles $sin\,\theta = n\lambda/a$.

Waves passing through one of two long, narrow slits will diffract in passing through each slit as described above, but in addition there will be interference with the waves from the other slit. According to geometry, shown in Picture D, here is constructive interference causing intensity maxima at points on the screen for which $sin\theta = \frac{n\lambda}{d}$, n=0,1,2…, d – the distance, that slits are separated.

Picture D. Diffraction scheme: double slit

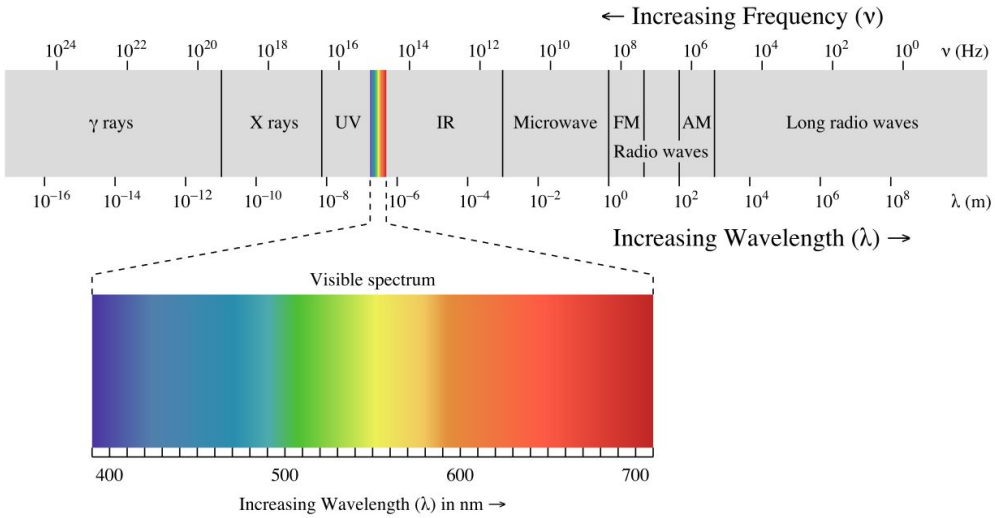
So how about the soap bubble – you ask?

Picture I. Interference in soap bubble.

The colors seen in a soap bubble arise from interference of light reflecting off the front and back surfaces of the thin soap film. Reflected light is coherent so the interference phenomenon occurs. Depending on the thickness of the film, different colors interfere constructively and destructively in

different places. That's way we see all these different colors by viewing in different angles. The same explanation can by applied for oil spill and etc.

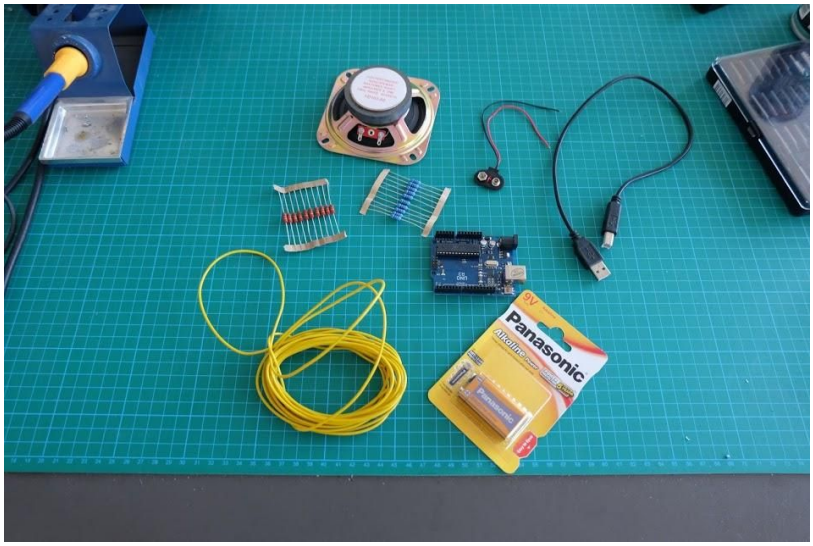
All these light wave principles apply for other waves – sound, waves found at sea and etc., and can be used for many experiments and technologies. Earlier was mentioned that every color is a different length electromagnetic wave, but you should know that electromagnetic waves are not only visible light. Exist thing, called electromagnetic spectrum (see Picture J) which shows the variety of electromagnetic waves. From spectrum you can see that visible light is very narrow part of spectrum but wave principles (like diffraction, interference and etc.) are suitable for all electromagnetic waves.



Picture J. Electromagnetic spectrum.

In this workshop we will explore so called Wi-Fi waves (~2.4 GHz) and their interference by constructing Electromagnetic Interference Detector.

Step 2: Part list



Electronic parts:

- Arduino Uno microcontroller
- Standard USB A/B cable, 3 ft. or longer
- 1-megaohm resistors
- Breadboard
- 3–5 feet of insulated solid core wire
- Fresh 9-volt battery
- Small-gauge wire stripper
- 8-ohm speaker

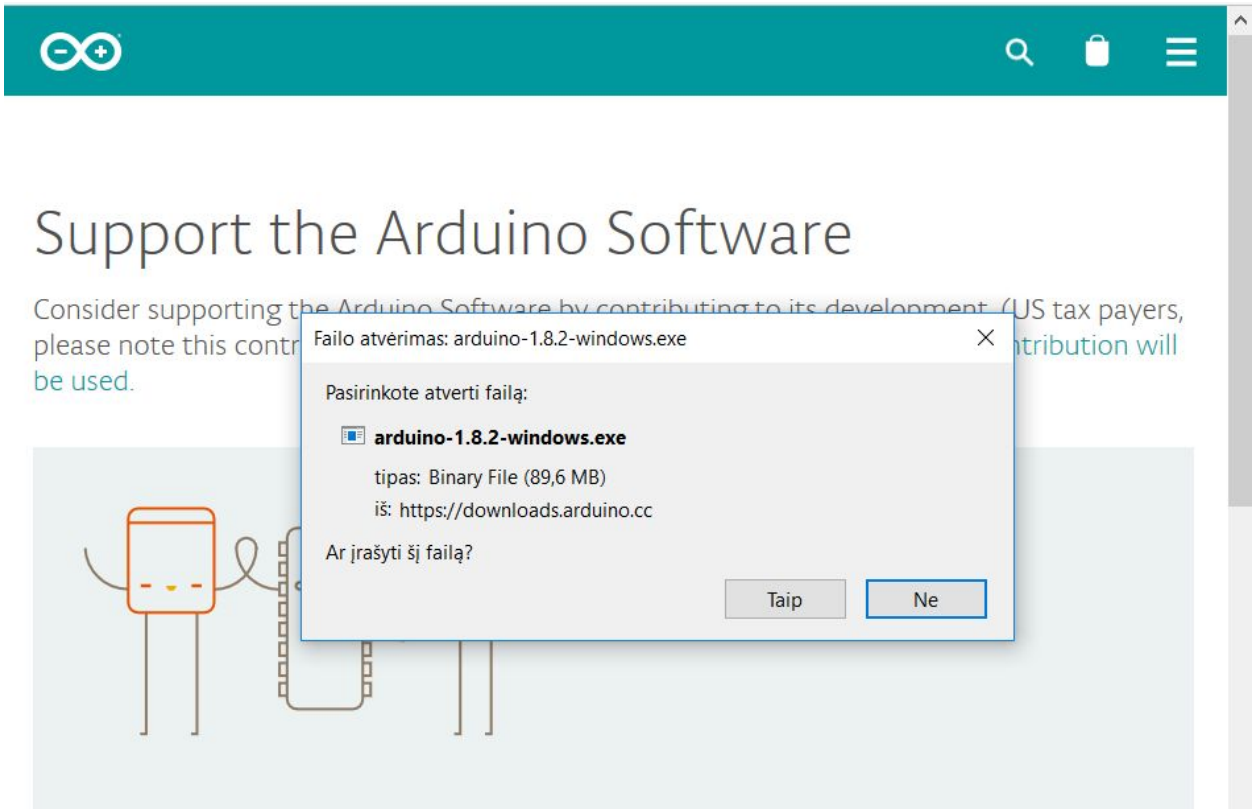
Photonic parts:

- Red, green or blue LED

Other parts:

The photonics parts can be bought by EYESTvzw.
The electronic parts can be bought by Fablabfactory.

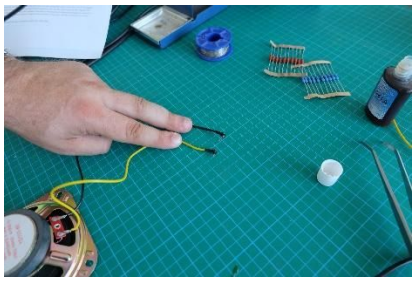
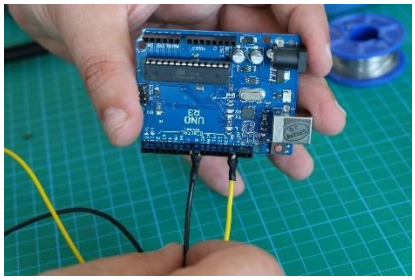
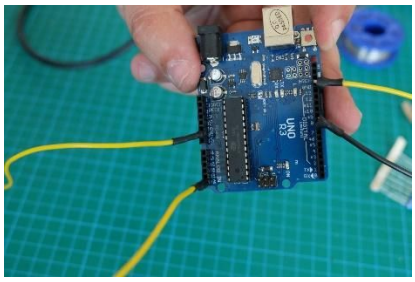
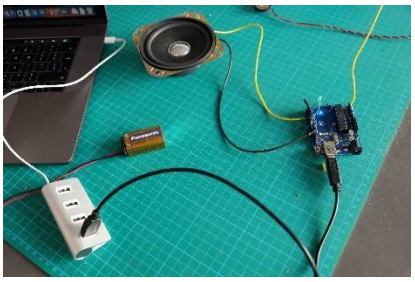
Step 3: Download and install the Arduino software



BASIC

To use Arduino, first install the free, open-source software that will let you install programs (called "sketches" in Arduino-speak) onto Arduino. This is easy to do: Find the software (available for Mac OS X, Windows, and Linux), along with instructions for installing and using it, at: arduino.cc/en/main/software

Step 4: Test the 8-ohm speaker

BASIC

Before we begin to build the EMI detector, be sure the 8-ohm speaker works:

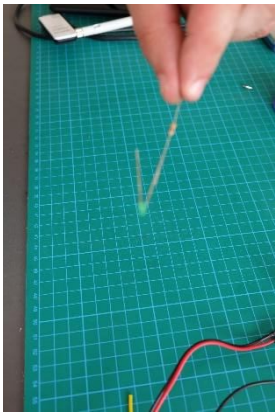
Step 1: Plug your 8-ohm speaker into Arduino as follows: the red lead into digital pin 8 and the black lead into the digital GND pin, along on the same line of pins on Arduino.

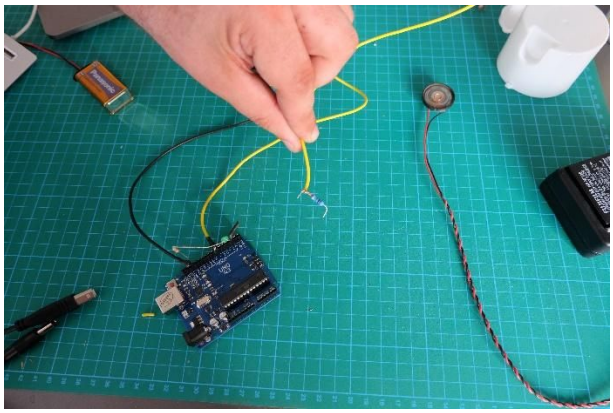
Step 2: Connect Arduino to your computer using the USB cable. (This cable powers Arduino and lets you upload sketches from the Arduino software.)

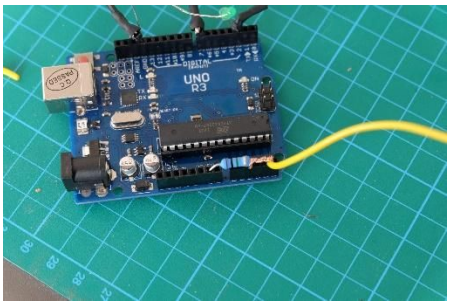
Step 3: Open the Arduino software. Find the sketch "toneMelody" at File | Examples | Digital | toneMelody. Load it onto Arduino, and run it.

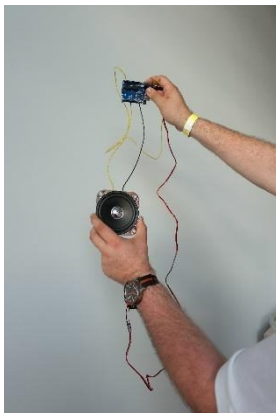
Did you hear a pleasing little melody come from the 8-ohm speaker when you ran the sketch? Then it worked. If not, check all your connections and try again.

Step 5: Construct the EMI detector









BASIC

Step 1: Cut a 3-foot-long piece of solid-core wire.

Step 2: Strip about 1.5 inches of insulation from one end of the core wire.

Step 3: Twist together one end of the 1-megaohm resistor with the stripped end of the core wire.

Step 4: Insert the twisted-together core wire/resistor into analog pin A5 on Arduino, and insert the free end of the resistor into one of the analog GND pins on Arduino, which can be found along the same line of pins.

Step 5: Insert one end of a jumper wire into digital port -9 on Arduino and the other to a pin on the breadboard.

Step 6: Insert one end of another jumper wire into Arduino's digital GND pin and the other into a pin on a different row on the breadboard.

Step 7: Connect the red lead of the 8-ohm speaker to a pin along the same row that's wired to digital port -9 on Arduino, and connect the speaker's black lead to a pin on the row wired to the digital GND port. (Note: You could also connect the speaker directly to Arduino but using the breadboard reduces the wear and tear on Arduino and better supports the speaker when you use the detector in mobile mode.)

Step 8: Connect Arduino to your computer with the USB cable

Step 9: Open the Arduino software, and load the Arduino Electromagnetic Interference Detector sketch into it; you can find the sketch at github.com/ejgertz/emwa | chapter-4 |

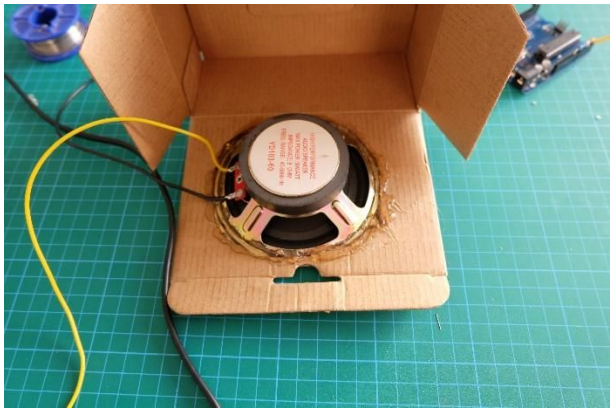
Step 10: Load this sketch onto Arduino.

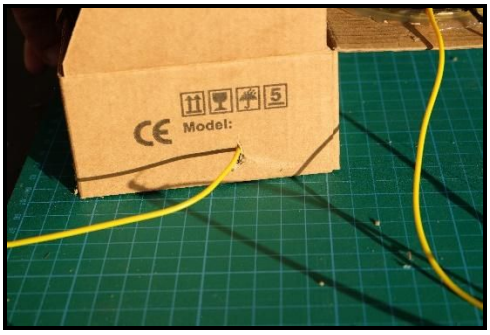
Step 11: Once you have uploaded the sketch to Arduino and Arduino restarts, you'll probably hear a cacophony of sound from the speaker. That's normal: Because Arduino is connected to your computer, it's receiving a flood of electromagnetic interference from the computer via the USB cable.

To make this detector really useful, we need to take it mobile.

VIDEO1: https://goo.gl/photos/kf3S72yk85i7y55j7

Step 6: Powering the EMI Detector in Mobile Mode

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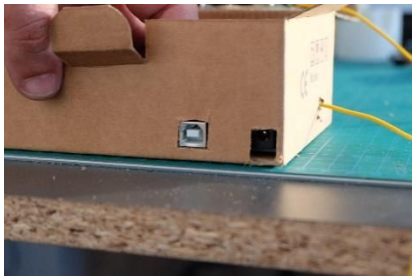
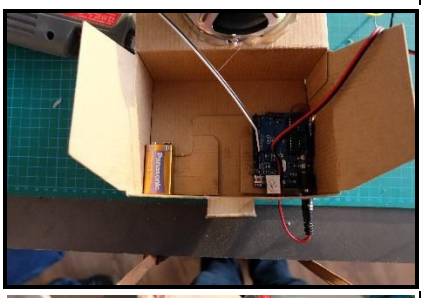
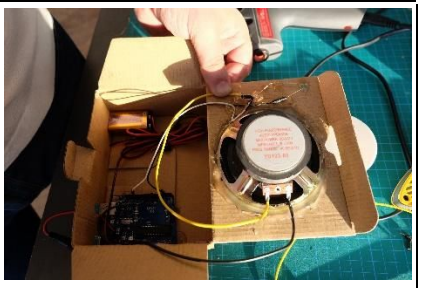

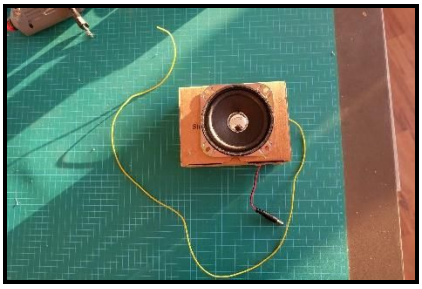

BASIC

Step 1: Carefully unplug Arduino from the USB cable.

Step 2: make your detector mobile by putting it into the box.

Step 3: Snap the 9-volt battery into the battery pack, and then plug the battery pack into Arduino's power port. The Arduino should start up immediately: the LEDs mounted onto the board should flash, and within a few seconds the EMI code should be up and running.

Step 4: Now take your detector for a walk around the room. While you'll hear a steady stream of white noise from the speaker, it should change in tone or squeal when the wire encounters

EMI—the louder or faster the noise, the more electromagnetic interference the gadget has detected.

VIDEO1: https://goo.gl/photos/F2Qa1jghyUiTYNSt6

Last step: End result & conclusions

What we learned?

• Day light consist of main seven colors: red, orange, yellow, green, blue, indigo and violet. Every color is a different length electromagnetic wave.
• Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of light around the corners of an obstacle or aperture.
• Diffraction can be used to separate different wavelengths of light using a diffraction grating
• Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude. Interference usually refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, surface water waves or matter waves.
• The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation. The other types of EM radiation that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet light, X-rays and gamma-rays.
• Diffraction grating can make electromagnetic waves interfere.

Concluding thoughts

Photonics is an amazing science which lets us find out more about electromagnetic waves generation, detection and manipulation. Some of the most beautiful and (some say) magical things in nature can be explained by this science. Today you have learned that electromagnetic waves (like light) can diffract and interfere. It happens in our daily life everyday (remember soap bobble example) but, also, you can use these wave properties for making amazing experiments – like constructing Electromagnetic Interference Detector.
This device converts invisible electric vibrations (standby power, the amount of electricity that constantly flows through some electronic devices, even when they‘re supposedly switch off or in standby mode) into audible sound. This gadget is one of the simplest environmental sensors that you can make your own.

The following part will always conclude a workshop of PHABLABS 4.0. Please add the names of your institution and that of your pilot fab lab and the logo's.

PHABLABS 4.0 is a European project where **two major trends** are combined into one powerful and ambitious innovation pathway for digitization of European industry:
On the one hand the growing awareness of **photonics** as an important innovation driver and a **key enabling technology towards a better society**, and on the other hand the **exploding network of vibrant Fab Labs** where next-generation **practical skills-based learning** using KETs is core but where photonics is currently lacking.

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This workshop was set up by the Center for Physical sciences and technology (Sergejus.Orlovas@ftmc.lt)

CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

PHOTONICS 21

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