SOUND RETRIEVAL BY DEMODULATING A REFLECTED LASER BEAM FROM A VIBRATING SURFACE

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Abstract

The project presented in this paper involves a machine that uses coherent light to retrieve voices and conversations that take place behind a window. It is quite an old invention that was firstly used by agencies and military forces. Nowadays however it is being used mostly by private investigators as a means of "bugging" private conversations. Although the laser microphone I describe below is not an "innocent" machine - meaning that anyone using it without a license could face a jail sentence [1], from a scientific point of view, the laser microphone encompasses many interesting theories as far as signal processing is concerned.

1. The main idea

The main idea: A beam of coherent light (laser) is "sent" towards a window. Behind the window is the sound source (e.g. conversation). The laser beam bounces off the window and returns to the machine, where it is collected by the receiver. The light that returns back has been modulated by the small movements of the window according to the amplitude of the sound. So we have an amplitude modulation. The modulated coherent light is then transformed into an electrical signal that is filtered and then amplified so that by wearing earphones, one can hear the same sound that transpires behind the window in the room.

2. The circuit

The circuit is supplied with 12 Volts dc. A switch controls the general supply to the machine. This switch (SW1) is connected to a resistor and a green LED. The SW1 is also connected with 2 IC's. The first is the IC LS780S09 and the second, the LS78S09. Both are voltage regulators. The LS780S09 is supplied with 12 Volts dc with an output of 9 Volts dc which supplies the second voltage regulator. The output of the second voltage regulator is 5 Volts dc. To prevent any unstable situation with the current, we use the electrolytic capacitor C12 (10 μF, 25 Volt). The output of each voltage regulator is connected with a fuse and then 2 switches. After the 2 switches there are ramifications at each one.

SW2 is connected with a blue LED and the variable resistor. The SW2 is also connected with the receiver's circuit. SW3 is connected with a red LED and a resistor, whereas another wire supplies the laser diode. The laser diode has an optical output of 0.9mW (Class II) with λ=650nm. The most valuable part of the circuit is the phototransistor L14G3 which transforms the light signal into an electrical signal that drives the MC3340P through a decoupling capacitor. A decoupling capacitor is used as an energy deposit in occasions where a sub circuit needs large amounts of current in a short time. If this happens to many sub circuits, the voltage to the machine will reduce dramatically and will cause many problems to the circuit. The decoupling capacitor is also useful in cases for driving IC's.

The input signal to the MC3340P can decrease or increase in dt time. This type of load in resistor R2, if not driven properly, could destroy the IC. The MC3340P is an electronic attenuator, exactly the opposite of an amplifier. The signal we drive to its input is being filtered and attenuated. At the output, we take a signal without being degraded to a very large degree. After exiting the attenuator, the signal is driven through the decoupling capacitor C4 to the input of the LM380N. The LM380N is an amplifier working in the acoustic frequencies range with a gain of 34dB.

Because the load used by the IC can take values with great differences, from high values to low values in a very short time, the R4 resistor and the capacitors C5 and C7 help to smooth operation and have better frequency response of the LM380N.

The signal that leaves IC2 splits into 2 paths:

i. The 1st path results in jack J1 where we can plug in headphones or a small speaker (4 to 20 Ohms). Between the V_{out} pin of the IC2 and J1 there is an electrolytic capacitor C6. This capacitor deposits energy that is used when there is a need for a large amount of energy within a short time period.
ii. The 2nd path connects V_{out} of IC2 with the LM741. This IC is a voltage follower, an operation amplifier in other words. It amplifies the signal from the LM380N so that it can be input to the micro-ampere meter M1.

To have the M1 working properly, more specifically to have the coil of the M1 working, we must amplify the signal we take from the LM380N, so that the signal is able to move the coil. For this reason we use the LM741. Diodes D1 and D2 are used to protect the amperometer from any reverse current, something that could destroy the indicator. As it is known, sound is not a "line" if we want to draw it in the x-y Cartesian System, but rather an ac signal, with positive and negative parts, similar to the sine/cosine currents taught in "AC theory". The electric signal that drives the M1 has neither shape nor period (T), but instead, very quick fluctuations. For this reason, the signal has to be rectified before it is supplied to the M1. That is why we use the 2 diodes D1 and D2. With the pot meter R8 and capacitor C11 we can adjust the sensitivity of the indicator. Increasing the value of capacitor C11 there is a slower return of the indicator to the 0 position, whereas by decreasing the value of C11, the indicator moves faster to the 0 position.

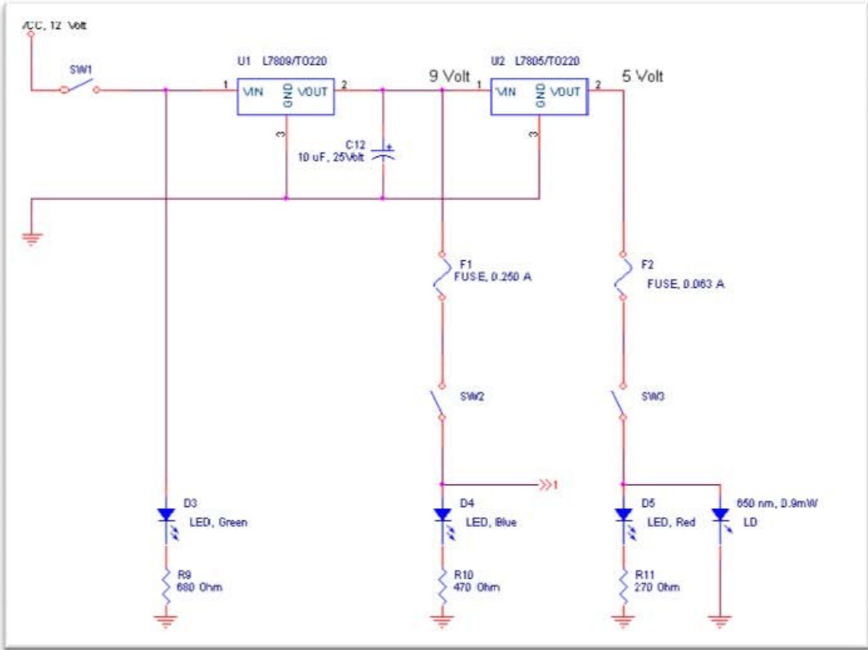

Figure 1

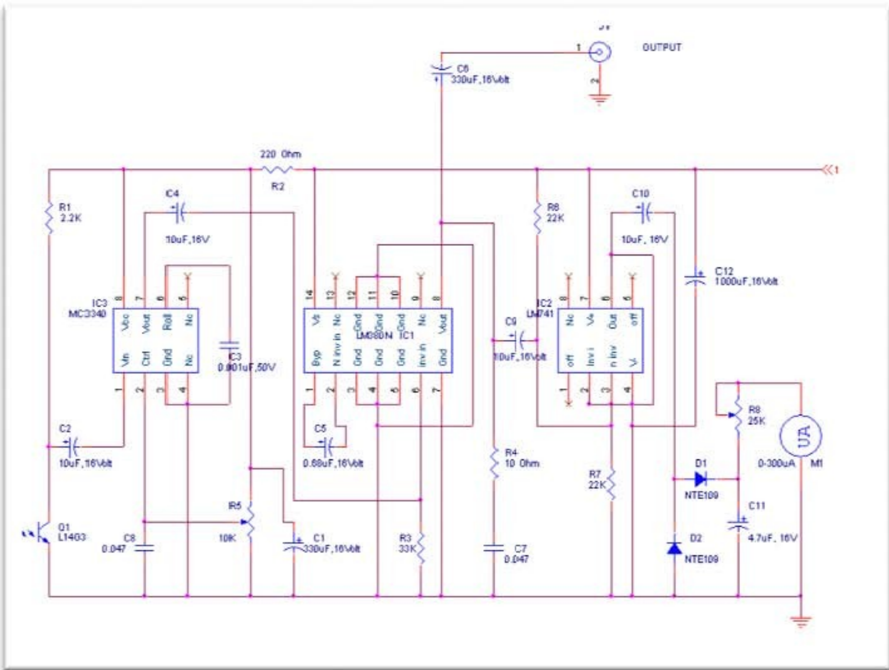

Figure 2

3. Improving the laser microphone:

The tripod on which the laser microphone is mounted could change with a system of servomotors so the alignment, receiver-reflected beam becomes easier. There is a difficulty in trying to align the receiver with the reflected beam. For this reason I have come up with several ideas such as using gases so as to visualize the invisible red laser beam. As known, the laser microphone adopts the very sensitive ampere-meter which helps in the alignment. If we could treat this signal so as to drive the servomotors' system, the procedure of the alignment could be done automatically. A very simple example, (the simplest block diagram in Automatic Control Systems) is shown in figure 3 below:

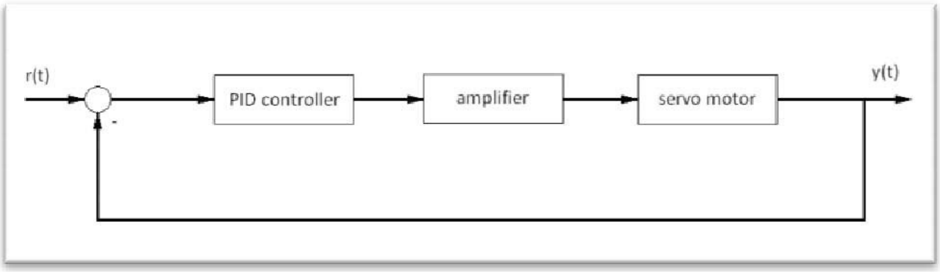

Figure 3

However, for the realization of this idea, we need at least 3 servomotors (7/1990 Teshima et al 318/567). [2]

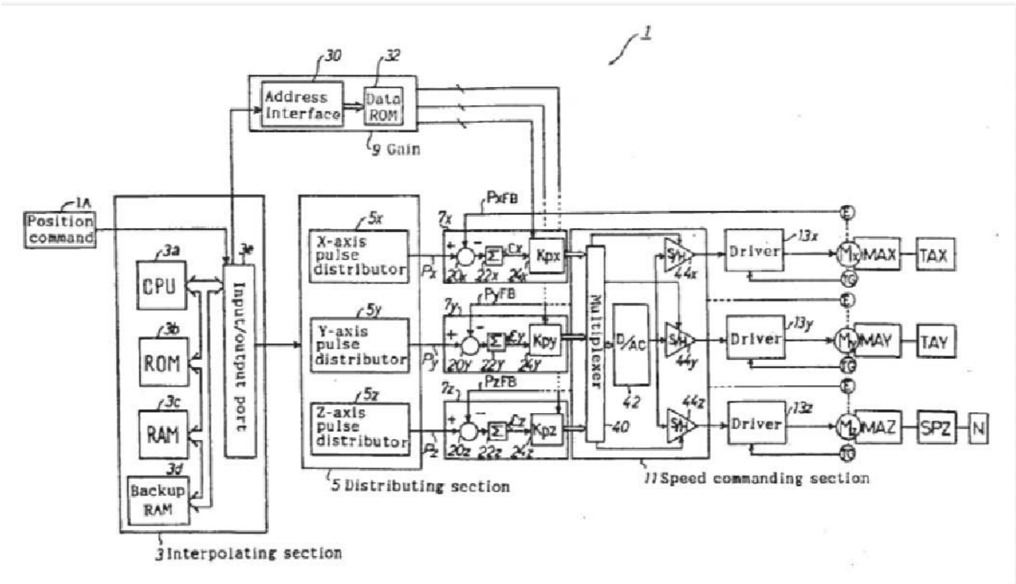

Figure 4

In the block diagram shown above (fig. 4), there are 3 servomotors and according to its inventor, it can successfully support more. The significance of this servomotor system is that it works with coordinates that it receives from the “position command” box. But how can the laser microphone somehow “find” the best position where the reflected beam is received by the machine?

One solution could be the use of a CCD camera mounted on a telescope with a cover angle to the target capable of receiving the laser beam [3]. To have the exact position where the entire system; (laser microphone-servomotors) should move, there must be program code (e.g. using MATLAB) which will suitable process the pixels that the camera receives in order to get the coordinates (x,y).

The CCD camera could also be used for another reason, i.e. for finding the distance between the position of the laser microphone and the target [4]. As well known by anyone who has used a simple laser pointer for presentations, if we target the laser pointer far away, the illumination of the dot is less than if we were to target it to a wall right next to us. This presents the first idea from the fact that the closer the object we target with the pen, the more luminous the dot appears and the further away the object we target with the pen, the less luminous the dot appears. We can revenue this characteristic of the laser and using a real-time image process of the camera, we can compute the relevant distance (laser microphone – target). In this case we are not interested in the reflected beam from the laser, but rather the exact position of the reflection from the window.

The laser diode that the laser microphone uses emits a red colour beam (650 nm). The receiver, L14G3 phototransistor does not receive only the light at 650nm, but all of the visible light (400 – 700 nm) and some from the IR spectrum (invisible). This results in “noise” in the sound we get from the output. This occurs because the sunlight and the ambient light demodulate within the laser light. A solution could be to use a band pass filter (600 – 700 nm) that would allow only the laser light to pass (650 nm) as shown in figure 5. [5]

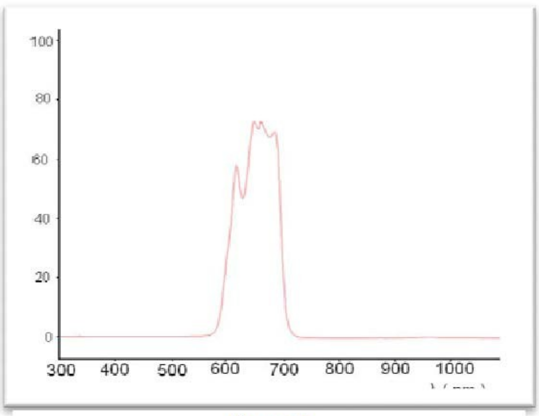

Figure 5

To achieve a much better alignment we can exchange the red laser diode (650 nm) for a green laser diode (532 nm). Green laser light is strong enough that its beam is visible.

This occurs because green colour stimulates the human eye more than the other colours [6]. With this characteristic of the mid-power laser diode, we are able to see the beam, thus making it easier to align.

4. Conclusion

In this paper I have presented the construction of an invention that proves of great interest to a graduate student concentrating in the fields of electronics, analogue circuits and digital processing methods. The main scope was not just assembling the machine, but through these ongoing experiments, to learn more, through practice, about the theory we study. The *laser microphone* is a very interesting invention and as proposed in section 4, many additions can be made so as to improve it. These improvements do, however, demand a great work effort. Finally, I believe that curiosity and attempts to understand machines that we do not encounter in everyday life, but most of the time read about in books, or see in movies, is a great incentive to urge someone to read and learn more about these machines and finally to propose new techniques for improvement.

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