Mobile phone audio combined with self-made laser light transmission frequency wireless actuated electromagnetic lock

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Abstract

This research project is to play music through the smart phone sound hole, and then to connect special-made Laser pointer to smart phone's music plug. The Laser pointer will light up when the smart phone's music starts playing. The result is that the music frequency is loaded into the light frequency. When solar panel receives light, it converts the frequency of the light signal into an electrical frequency signal. The current is amplified through the power amplifier and then the amplified current flows in sound recognition module. The sound recognition module performs audio comparison on the set sound signal, and after the comparison is correct, the output voltage activates the electromagnetic switch on the door to open or close. The main purpose of the present research is to provide an acousto-optic control lock device for performing electrical signal conversion on a specific sound command signal by an acousto-optic conversion module, thereby improving the reliability and safety of opening or closing the door lock.

Key words: laser pointer, electromagnetic lock, sound recognition module.

I. Introduction

Traditional electronic remote controls [1-2] have been widely used in iron rolling doors, car central locks, scooter electronic locks, and various types of door locks. A signal transmitter is configured in the remote control to send the control signal for opening/closing the door to a signal receiver. The signal receiver is usually connected to an actuation circuit, which then turns on or off the connection mechanism to open/close the door. Most of remote controls use an infrared signal or a radio frequency (RF) signal [3-5] as the control signal required for opening/closing the door. Accidentally, losing or forgetting the remote control would result in being locked out. Moreover, electronic remote controls fail to work when they run out of battery power. Such incidences cause inconvenience to the users of traditional remote controls. Further, with technological advancement, electronic remote controls are susceptible to replication and theft, and their security is gradually being challenged. In this view, traditional electronic remote controls need to be improved to eliminate the inconvenience and lack of security.

II. Materials and Methods

The proposed model is based on a control lock device, particularly an audio-coupled laser-actuated electromagnetic lock device mounted on a door plank for users to open or close the door using audio. An audio-coupled laser-actuated electromagnetic lock device consists of a transmitting unit, a receiving unit, a recognition unit, and an actuation unit. The transmitting unit of the proposed device comprises of an acoustic receiver and an acousto-optic conversion module, and the receiving unit is configured with an optical receiver. The acousto-optic conversion module converts a specific audio command signal into an electrical signal, thereby improving the reliability and safety of door locking or unlocking. The transmitting unit can be embedded in a mobile phone to open or close the door lock. Thus, users would not need to carry the remote control; this presents a higher level of convenience.

A. Apparatus.

The energy conversion module contains a power amplifying circuit, signal input and output terminals, and a power terminal. When the energy conversion module is operating, its temperature increases. The positive and negative poles of the solar panel are connected to the input pins of the energy conversion module using wires. Because ambient light in the environment can affect the solar panel and generate noise, the panel has been modified to comprise a masking structure. The energy conversion module adopts a low-voltage LM386 [6-7] chip manufactured by US National Semiconductor. Such chips are commonly used in low-voltage consumer products to minimize peripheral chip components. The LM386 chip's voltage gain is typically set to 20. However, by adding an external resistor and a capacitor between pins 1 and 8, the voltage gain can be arbitrarily adjusted up to a maximum value of 200 (Fig. 1).

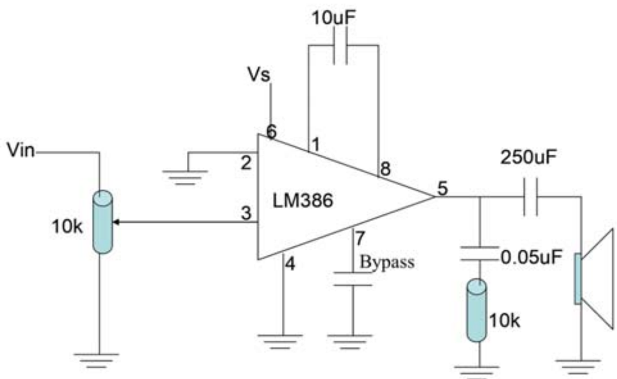

Fig. 1. Circuit diagram with a gain of two hundred.

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B. Electromagnetic lock mechanism modeling

Fig. 2(a) presents the mathematical model [8] with physical parameters, with the equation of motion as follows:

$$m\ddot{x} + c\dot{x} + kx = f(t) \tag{1}$$

Where *m, c,* and *k* represent the mass, damping coefficient, and spring constant, respectively, which are the physical quantities of the system's mass, damping, and spring components. Fig. 2(b) presents a mathematical model with modal parameters. By dividing (1) by *m* and substituting the variables, the equation of motion for the physical parameters can be rewritten in modal parameter form, as follows:

$$\ddot{q} + 2\xi\omega_n\dot{q} + \omega_n^2 q = N(t) \tag{2}$$

where

$$\omega_n = \sqrt{\frac{k}{m}}\ ;\ \xi = \frac{c}{c_c}\ ;\ c_c = 2m\omega_n = 2\sqrt{mk}\ ;\ q(t) = x(t)\ ;\ N(t) = \frac{f(t)}{m}$$

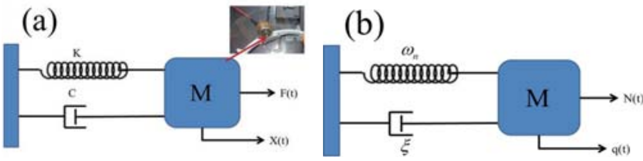


Fig. 2(a). Mathematical model with physical parameters.(b). Mathematical model with modal parameters.

c_c denotes critical damping coefficient; ξ denotes the damping ratio; ω_n denotes natural frequency; x(t) denotes physical coordinate; f(t) defines physical force; q(t) defines modal coordinate

Each conversion between domains, such as conversion from a mathematical model with physical parameters to one with modal parameters, or conversion of a mathematical model with modal parameters into one with frequency parameters, has a corresponding equation (Fig. 3).

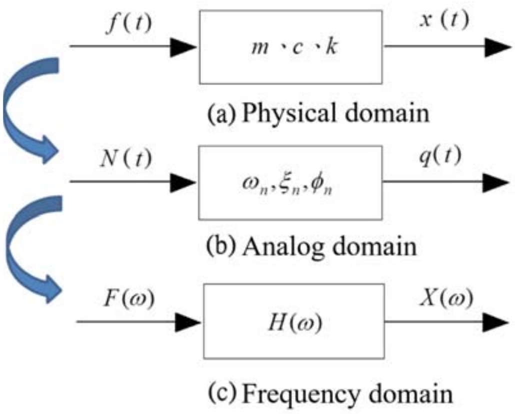


Fig. 3. Flowchart of parameter conversion in various domains.

C. Response analysis

Harmonic response analysis: Harmonic excitation force is set as the external force (f(t)=F $e^{i\omega t}$). By substituting x(t)=X$e^{i\omega t}$ into the equation of motion, the frequency response function is obtained, as shown in (3).

$$H(\omega) = \frac{X}{F} = \frac{1}{(k - m\omega^2) + i(\omega c)} = \frac{1/m}{(\omega_n^2 - \omega^2) + i(2\xi\omega_n\omega)} \tag{3}$$

Using (3), the frequency response function can be converted into a function of physical or modal parameters, which is related to the harmonic excitation frequency (ω).

Transient response analysis: If the input condition f(t) , initial conditions x_0 and v_0 , and system content (e.g., the physical and modal parameters) are known, the time-domain output response of the system can be obtained using the following equation:

$$x(t) = e^{-\xi\omega_n t}\left(A\cos\omega_d t + B\sin\omega_d t\right) + \int_0^t f(t)h(t-\tau)d\tau$$
$$\omega_d = \omega_n\sqrt{1-\xi^2};\ h(t) = \frac{1}{m\omega_d}e^{-\xi\omega_n t}\sin\omega_d t \tag{4}$$

Where ω_d denotes the damped natural frequency; *A* and *B* are random constants defined by the initial condition; and *h*(*t*) represents the unit impulse response function of the system.

Spectrum response analysis: If the frequency domain can be presented as the power spectral density (PSD) [9] function *x*(*t*), and the frequency response function is known, the frequency domain response can be obtained through spectrum response analysis, as shown in (5).

$$G_{xx}(\omega) = |H(\omega)|^2 G_{ff}(\omega) \tag{5}$$

Where $G_{xx}(\omega)$ denotes the physical coordinate and *x*(*t*) denotes the PSD function.

Fig. 4 depicts the circuit diagram of an audio-coupled laser-actuated electromagnetic lock device. In the first embodiment of the proposed device, the audio-coupled laser-actuated electromagnetic lock comprises of a light-emitting diode (LED) and a modulation circuit . The LED is used to generate an optical signal, and the modulation circuit is electrically connected to the audio receiver and LED. In the second embodiment , the receiving unit composes of an amplification circuit that is electrically connected to an optical receiver to amplify its output electrical signal. In the third embodiment , the optical receiver is a solar panel. In the fourth embodiment , the solar panel and door lock are mounted on a door plank . In the fifth embodiment , the recognition unit is configured with a comparator to compare the electrical signal with a preset signal and generate an actuation signal if the comparison result is the same . In the sixth embodiment , the recognition unit has a storage that stores the preset signal . In the seventh embodiment , the actuation unit comprises an electromagnetic actuator for opening or closing the door lock. In the eighth embodiment, the transmitting unit is built into a portable electronic product, either a smartphone or a tablet. In the ninth embodiment, the audio receiver is a monophonic plug, which is inserted in the sound port of a portable electronic product. As described earlier, acousto-optic control lock devices of the proposed model can open or close the door lock through a specific audio command signal, thereby improving the reliability and safety of the door lock, as well as preventing the lock key from being replicated or stolen. In addition, the transmitting unit embedded in the mobile phone enables the lock to be opened or closed without the use of a remote control, making it convenient for the user. The proposed model is suitable for long-distance transmission because an audio command signal is replaced with an optical signal and a specific audio signal is transmitted, thereby enhancing convenience.

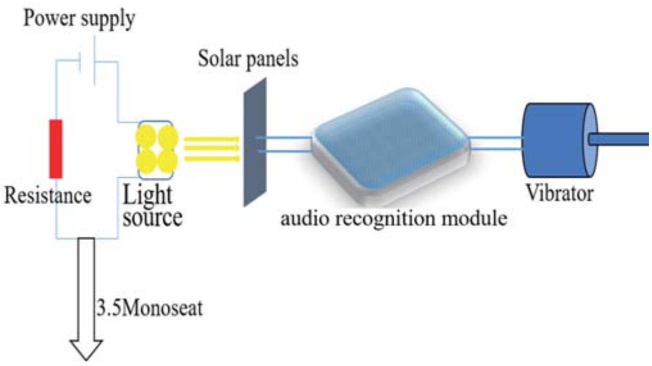


Fig. 4. depicts the circuit diagram of an audio-coupled laser-actuated electromagnetic lock device.

The objective of system modal analysis and testing is to develop specific analysis procedures and testing and measurement methods to obtain a mathematical model of the sound vibration mechanism. This model can be presented in the form of mathematical model with modal or physical parameters. The analysis process flowchart is presented in Fig. 5.

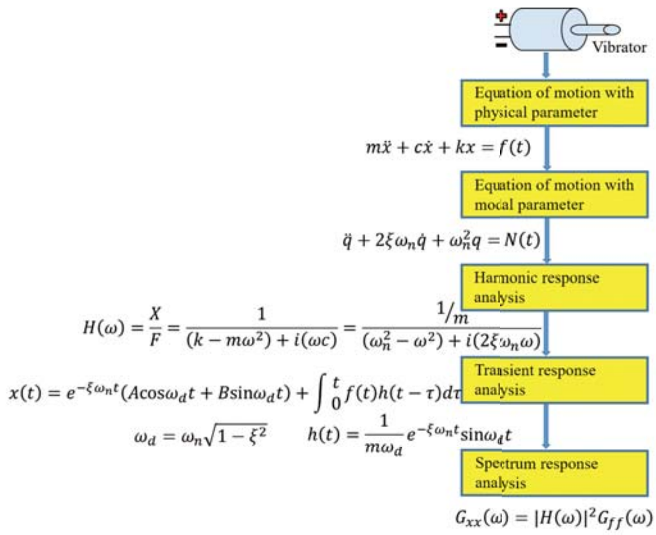


Fig. 5. Flowchart of analysis of sound vibration mechanism.

III. Results

A. Speech endpoint detection

The channel adopted in this experiment is mono. Because different volumes generate different amplitudes, audio signals are normalized to unify amplitudes and obtain a valid frame range for subsequent signal processing. Human speech often contains aspiration or friction, which can render the detection of sound energy difficult due to its low energy. The zero crossing rate in the endpoint detection method [10] can be employed to correct the endpoint range and extract an entire syllable (Fig. 6).

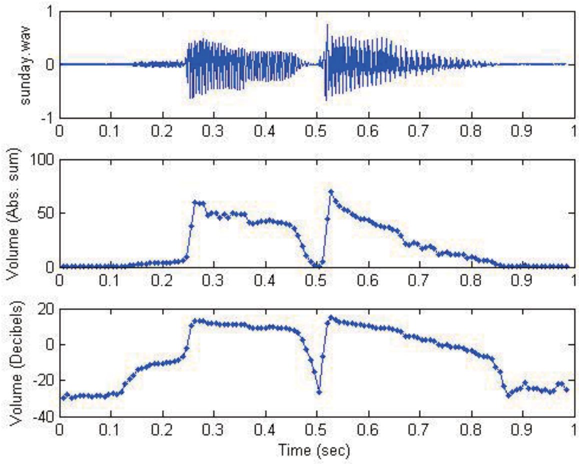
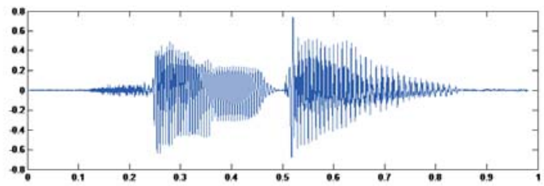


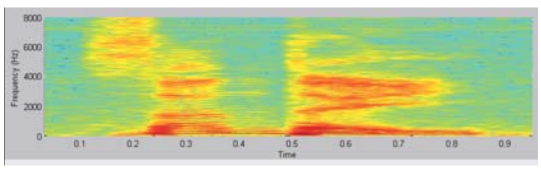
Fig. 6. Sampled voice signals in the time domain after ZCR calculation.

B. Feature extraction

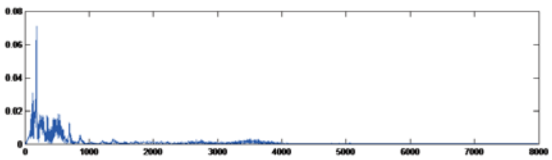
Signal characteristics are difficult to be recognized by observing changes of the amplitude value of an audio signal in the time domain (Fig. 7(a)). Converting the audio signal into a spectrogram (Fig. 7(b)) allows sonic characteristics to be identified. The amplitude value of an audio signal in the time domain is often converted to an energy distribution in the frequency domain for observation. Various energy distributions in the frequency domain represent different speech characteristics. A signal in the time domain changes rapidly and constantly, leading to inaccurate observation. Therefore, the most commonly used technique is conversion of the audio signal from the time to the frequency domain, thereby determining the spectral characteristics of various sounds through their energy distribution. The spectrum is a representation of a time domain signal in the frequency domain and can be obtained by performing FFT on the signal. The result is presented as a spectrogram [11], with the amplitude or phase as the vertical axis and the frequency as the horizontal axis (Fig. 7(c)).



(a)



(b)



(c)

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Fig. 7(a). Amplitude value of audio signal, where fs (44100) is the sampled frequency. (b). Audio signal spectrogram. (c). Audio signal spectrum.

IV. Discussion

The acousto-optic control lock in the proposed device can open or close a door lock through a specific audio command signal, thereby improving the reliability and safety of the door lock, and preventing a key from being replicated or stolen. In addition, the transmitting unit embedded in the mobile phone enables a door lock to be opened or closed without a remote control, making it convenient for the user. This model is suitable for long-distance transmission because the audio command signal is replaced with an optical signal and a specific audio signal is transmitted, thereby further enhancing convenience. The claims with respect to the proposed model are as follows:(1) Elimination of inconvenience caused to people who forget to carry their keys.(2) Elimination of the need to carry multiple keys due to the laser-actuated electromagnetic lock device coupled with mobile audio.(3) Subversion of the concept of opening a door with a key. With a mobile phone, a user can open multiple doors and set different opening passwords for each door.(4) Significant reduction of the need for metallic materials for creating keys, and elimination of the requirement for electroplating, which causes great damage to the environment, thus enabling mitigation of ecological pollution.

V. References

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