Mechanical gear footstep power generation using a mini generator with buck and boost selectors

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ABSTRACT

In this research, we intend to build a floor-based power plant that produces energy using a mechanical generator drive. The drive system uses a two-gear transmission system with a different number of teeth, resulting in varying torque and speed. The large gear will stick directly to the floor, causing it to spin when the floor is stepped on, and then the small gear will spin the generator quickly. The buck and boost selector systems are powered by fluctuating voltage from the generator. If the voltage produced by the generator is greater than 5 V, the system will reduce it; otherwise, the system will increase the voltage. This selector system uses several modifications of the current circuit between rectifiers, which function to rectify the generator output when the generator rotation changes, a voltage divider is useful for dividing the generator output voltage. The pressure before and after the selector system was measured by applying force on the floor to 15 people with varying loads. The result shows that the buck and boost selector system can work properly, and the nominal output voltage of the generator is around 5 V as needed.

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1. INTRODUCTION

The most important form of energy in the modern world is electricity. Electricity is essential to the functioning of many aspects of human life in the modern world. Many public facilities, such as train stations, hotels, shopping malls, movie theaters, and airports, use modern technology as a means of improving the work of a place. Electricity is the primary power source used to run the facilities in these types of public facilities, such as train stations, hotels, shopping malls, and movie theaters. Walking is one of the activities that causes humans to expend a significant amount of energy daily. In public buildings, where a large number of people walk throughout the day, having floors that generate electricity will be very useful [1].

Among all energy sources that can be extracted from human motion, footstep motion has the highest potential for energy (about 67 W, estimated in [2]). However, the low movement frequency and limited vertical deformation of the footwear make collecting energy from footsteps a big challenge [3]. Different mechanisms have been investigated to overcome these problems, such as gear trains [4] or frequency up-conversion [5] used to increase the excitation frequency, a rotary arm [6], or a trapezoid-shaped slider [7] used to generate rotation from the shoe distortion. However, all these devices still have the issues of complications, bulk, and high costs. The most commonly used energy harvesting mechanism based on footstep generators is the piezoelectric mechanism [8]–[14]. However, the amount of energy produced by piezoelectric is relatively small, so it can't be reliable and efficient to apply in public spaces.

Mechanical electricity-producing floor gears that use buck selectors and boost converters can be an alternative to the use of low-power tools or technology that is typically utilized in public facilities. By utilizing the unused energy that people produce as they walk across floors, this is possible. To function or operate, low-power technology typically employs a 5 VDC voltage. The selector system must be configured in such a way that it can choose a voltage that is either greater than or lesser than 5 VDC for the output to be in the vicinity of 5 VDC. This type of technology uses very little power and can come in the form of smartphones, tablets, fans, and power banks.

This research begins with the design of a gear mechanical system to drive a generator that will be installed under the floor and stepped on by pedestrians. The system's gears will be the ones driving the generator. In this experiment, a 12 VDC generator transforms the pressure that pedestrians apply into an electrical current. The mechanical energy that results from the force that pedestrians exert on the floor mats will power the generator that generates electricity. Nandan and Trivedi [15], using the stepped-on method, the voltage that is produced by the footrests of individuals who have varying body weights will be measured and then compared as a sample. The output of the generator will be connected to the buck selector circuit as well as the boost converter circuit. This will allow approximately 5 V to be obtained from the generator. This circuit makes use of the working principle of a single pole double throw (SPDT) relay, which employs the normally closed (NC) and normally open (NO) functions. For the input at the relay coil terminal to be chosen, a voltage divider circuit needs to be used.

2. RESEARCH METHOD

2.1. Mechanical electrical generating floor gear

Electricity-generating floors are an alternative form of energy generation that converts the energy of a person's footsteps into electrical power [16]. The force exerted by pedestrians can be converted into rotary motion so that it rotates the alternator, which will produce a potential difference or voltage. This is accomplished by providing a mechanical system using gears that convert the force into rotary motion. Mechanical electricity-generating floors use an alternator as a power plant.

In this study, Figure 1 shows an electricity-generating floor. A floor designed to generate electricity was used, as shown in Figure 1(a). Walkers exert force on the floor, causing the mechanical system to rotate the alternator or generator and generate electrical energy. An alternator that is rotating transforms pedestrian energy, which is mechanical energy, into electricity. Figure 1(b) illustrates the mechanical components used in the tool to ensure that it works properly and as expected. The shock breaker, crank lever, gears, axle shaft, generator, timing belt, and frame are the mechanical components used to support the mechanical system and make it work properly. Table 1 shows the detailed specifications of the major mechanical components used in the proposed mechanical footstep power generator.

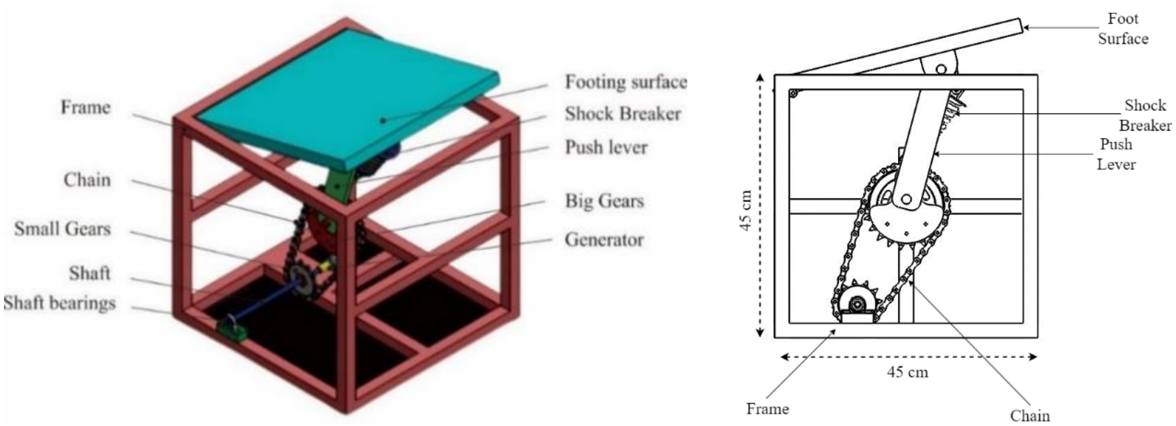
In a system that can be driven, gears are one of the mechanical components that serve the dual purpose of transmitting power while also transmitting rotary motion. Gears are not only used in the construction of vehicles but also in the construction of systems that convert rotary motion to linear motion or vice versa [17]. To connect two gears utilizing a timing belt, which is a type of belt that is frequently utilized in applications dealing with motion transfer. The construction of timing belts has uniformly spaced serrations. The gears that were utilized in this investigation were either reduction gears or various shaft gears. This gear has a different shaft, and it is part of a configuration that uses a timing belt to connect two gears that have different shafts [18].

The crankshaft is a component of the engine that is directly connected to the piston. When the piston moves from the top dead center to the bottom dead center, and so on, it causes the crankshaft to rotate in a circular motion [19]. The authors modified the work function of the crankshaft and piston lever in this study so that when the lever pushed the crankshaft, which has a unique shape, from the top dead center to the bottom dead center, the crankshaft assisted the lever in returning to top dead center.

There are two types of generators, namely alternating current (AC) generators and direct current (DC) generators. The difference between these two generators lies in the construction of the coils. The coil in the DC generator is located on the rotor, while the coil in the AC generator is located on the stator [20]. This study uses a DC motor with a type of PG28. A DC motor can be used as a motor or generator. When the rotor lever on this motor is rotated, it will produce a potential difference in voltage between the two poles.

2.2. Buck selector and boost converter system

The operational functionality and capabilities of buck and boost converter selector systems are derived from the underlying working principle of relays, which possess NC and NO contacts, respectively. It is expected that this system, with the inclusion of supplementary circuits such as rectifiers, voltage dividers, and relay module circuits, will possess the capability to choose the input voltage and direct it towards either bucking or boosting, as illustrated in Figure 2. This circuit has been modified; these modifications serve the purpose of rectifying the output of the generator when there are changes in its rotation. Additionally, the system incorporates a voltage divider that facilitates the division of the generator output voltage, ensuring that the selector remains inactive when the voltage falls below 5 V. Furthermore, a relay circuit is integrated to enable the continuation of the generator's output voltage to the buck or boost converter.



(a) (b)

Figure 1. Electricity generating floors view in the form of (a) 3D design of mechanical electric generating floor and (b) side view of the mechanical construction

Table 1. Specification of major components in the proposed mechanical footstep power generator

	Specification	Value	Gear 1	Gear 2
Gear	Gear thickness	mm	9	9
	Gear diameter	mm	23.5	7.5
	Number of teeth		43 T	13 T
Chains	Distance between gear shafts	mm	190	
	Size	mm	428	
	Length	mm	895	
Spring	Spring length	mm	125	
	Wire diameter	mm	4.2	
	Inner diameter	mm	48	
	Outer diameter	mm	56	
	Total number of coils		5	
	Spring stiffness	N/mm	-	

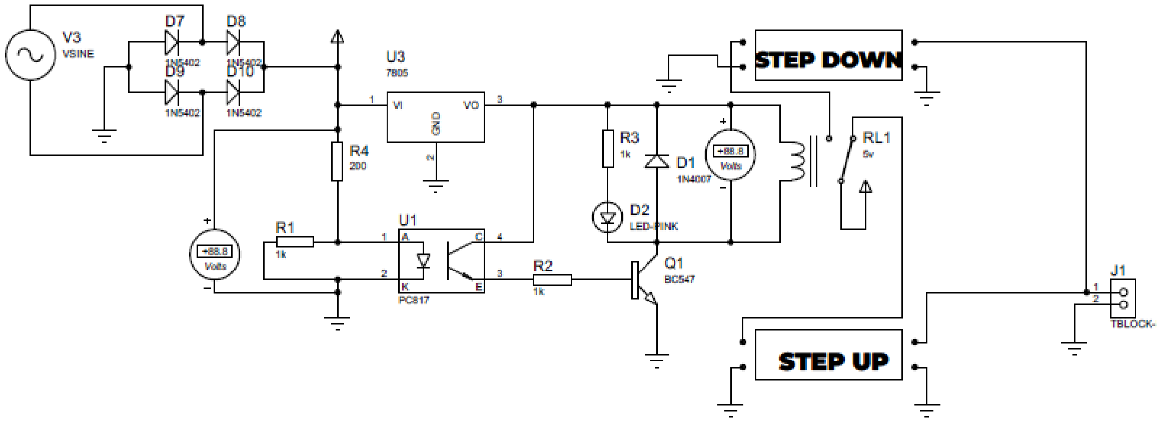


Figure 2. Schematic diagram of the selector circuit

An AC circuit that is converted into a DC circuit is referred to as a rectifier circuit [21]. The function of the voltage divider circuit is to reduce the initial high input voltage to a lower value at the circuit's output [22]. A relay is a type of electronic component that performs the duties of a switch in an electrical circuit. The working principle of the relay is based on the coil. If voltage is applied to two of the coil's poles, the relay will move the iron rod, shifting from a position where the common (COM) pin is connected to NC to a position where the COM pin is connected to NO [23].

In this particular investigation, a buck converter of type LM2596 was used. Buck converters are a type of DC-DC converter circuit that can reduce the input voltage [24]. And make sure to use a boost converter of type MT3608. The boost converter is a type of DC-DC converter that can raise the voltage to a greater level [25].

2.3. Block diagram of an electrical generating floor mechanical system

Figure 3 illustrates how the electricity-generating floor system works to generate voltage. In the design of the energy system, the pressure exerted by pedestrians on the floor will move the large ratio gears, which are then connected to the small ratio gears to produce faster rotation. This rotation will cause the DC generator to spin and produce more electricity than if there was no system for transmitting electrical energy or potential difference. In this study, data is collected by applying a force to the footing floor mat, which then rotates the gears and rotates the generator to generate electricity, which is selected by the buck selector and boost converter systems. Force is applied by 15 people using various weights and stamping techniques.

2.4. Testing of gear mechanical electrical generating floor

This test is divided into several stages, which are as: i) Applying a force to the floor mat while keeping the generator's output voltage over 5 V allows the selector system to function properly, with the selector system's output having a value of around 5 via the LM2596 buck converter and ii) The boost converter mode is tested by applying a force to the floor mat while keeping the output voltage below 5 V so that the selector system can function effectively with a marked output from the selector system with a value of around 5 through the MT3608 boost converter. The entire system was tested by having 15 people with varying body weights stamped on it. These 15 people of varying weights will exert force on the floor with one stamp, ten stamps in ten seconds, ten stamps in eight seconds, and ten stamps in four seconds.

3. RESULTS AND DISCUSSION

The goal of this study is to build an electricity-generating floor out of a tiny generator whose output voltage is selected using a buck selector and boost converter system to provide a voltage of roughly 5 V. In this research, several parameters can be measured to obtain optimal experiment results for the developed system. The mechanical footstep electric generator device is used as an electricity generating device, then a selector series is used to convert and stabilize the voltage output, while the oscilloscope and multitester are used as instruments for measuring output power.

To get varied and accurate results, a measurement method was used that involved several different variables, such as the user's body weight and the length of time he stepped on the plate. Testing was carried out 10 times for each variable and the average of the measurement results obtained was taken. Table 2 shows the sample output voltage generated by the device with 10 times foot strikes in 8 seconds.

Figure 4 is showing voltage data graph. The voltage data for one stamping is displayed in Figure 4(a). During the testing, it was discovered that the relationship between the weight of the pedestrian and the output voltage created by the generator is not directly proportional to one another. This was discovered when the tool was given one pedal. When this information is processed by the selection system, it will also affect the output voltage.

To get more accurate data, another experiment was conducted with varying the variable of time the floor gets struck. In the experiment with stamping variations, Figures 4(b) to (d) illustrate the results of 10 stampings in 10 seconds, 10 stampings in 8 seconds, and 10 stampings in 4 seconds, respectively. It is clear from the graph that the weight of the pedestrian does not have a direct proportional relationship with the amount of voltage that is produced by the generator. Nevertheless, the selector system can choose the output voltage of the generator and can produce a voltage of approximately 5 V. In this experiment, it was also discovered that the rate at which force is applied to the floor mat is directly proportional to the magnitude of the output voltage produced by the generator. This was demonstrated by displaying a graphic comparison of the results of 10 strokes in 10 seconds, 10 strokes in 8 seconds, and 10 strokes in 4 seconds.

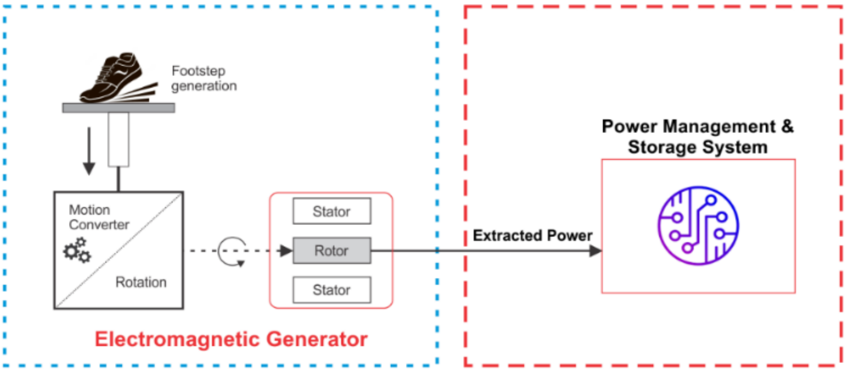


Figure 3. Block diagram of the electrical generating floor mechanical system

Table 2. Output voltage data with 10 strokes in 8 seconds

Body weight (Kg)	Voltage before selector (V)	Voltage after selector (V)
37	8.82	5.11
48	7.77	5.03
50	9.24	5.07
51	8.64	5.07
55	7.89	5.03
58	9.10	5.11
59	5.42	4.93
60	9.56	5.11
61	8.22	4.69
65	8.77	5.11
68	7.45	5.00
70	8.80	5.11
74	7.90	5.11
76	7.99	5.09
82	8.98	5.11

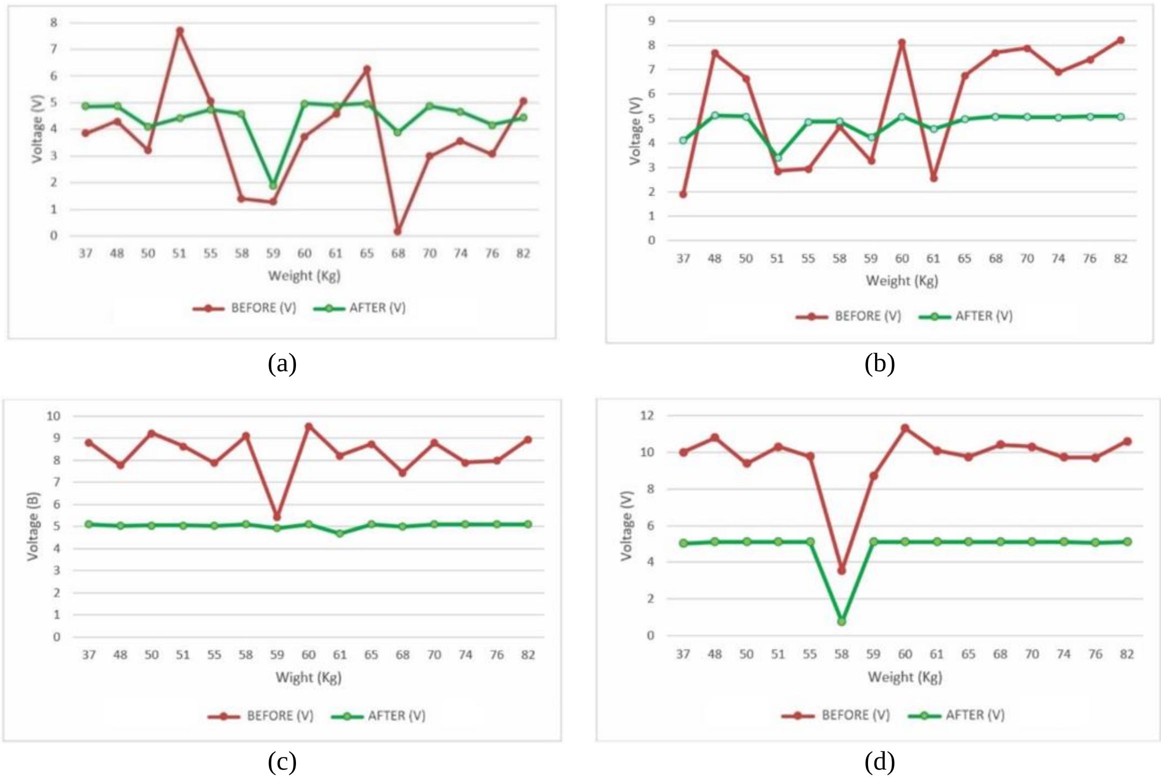


Figure 4. Voltage data graph for (a) one-time stamp, (b) 10 stamps in 10 seconds, (c) 10 stamps in 8 seconds, and (d) 10 stamps in 4 seconds

4. CONCLUSION

A gear mechanical electricity-generating floor is one option for generating power by harnessing pedestrian energy. The functioning principle of this electricity-producing floor is to generate a stepping force on the floor mat, which then moves the gears and rotates the generator to generate voltage. This floor's voltage output can reach 11 V. The output voltage created by this floor is directly related to how rapidly the force is pushed to the floor rather than directly proportional to the pedestrian's body weight. The buck and boost converter selection systems can direct the generator's output voltage to either the buck converter LM2596 or the boost converter MT3608. The selector system produces a voltage that is significantly different from 5 volts because charging the magnetic field in the inductor and charging the electric charge in the capacitor has not filled it. It is intended that this research can be refined and expanded by focusing on the mechanical system of the floor, specifically the part of the floor mat that does not protrude when subjected to force to bring comfort to pedestrians. In the charging portion of the inductor magnetic field and the electric charge of the capacitor, the selector system is produced.

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