Transportation noise pollution: Impact and Opportunities

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Abstract

In this paper, the impact of the transportation noise pollution and the opportunities to use the transportation noise for energy harvesting is presented. The noise generated from the various sources of transportation have been discussed in detail. Ambient energy harvesting techniques can be utilized for this purpose and clean energy can be produced utilizing transportation noise pollution. Simulations and experimental studies have been carried on Proposed Single Stage Bridgeless Boost Converter (SSBBC) circuit that yields best results with 48µH inductor with maximum power of 400µW for highway noise, 237.16µW for railway noise and for aircraft launchpad operations proposed circuit yields better results on 20µH with maximum output power of 1052.64µW.

Keywords: Ambient energy; Energy harvesting; Transportation noise; Boost converter; Acoustic transducer; Proteus.

1. INTRODUCTION

Nowadays, noise pollution is quite common in metro and urban areas where there is more traffic which is one of the main sources of noise. Noise pollution is the unwanted noise present in the environment. The noise pollution is categorized into two types: man-made noise pollution and natural noise pollution. The transportation noise pollution is the highest contributor of the man-made noise pollution [2]. Transportation noise refers to the noise generated from the various sources of transportation such as trains, ships, airplanes, and heavy roadside vehicles [1] [14]. The transportation noise pollution can havesignificant impacts on human health and the environment. Figure 1 show types of noise pollution. Natural noise pollution is associated with natural phenomena such as lightning, thunder, earthquakes etc. On the other hand, man-made noise pollution is human intended noise such as noise in the heavy industries, noise from the transportation medium and the noise from the neighborhood. Transportation noise pollution is classified into four categories. Each category is explained in the further sections of this paper in detail.

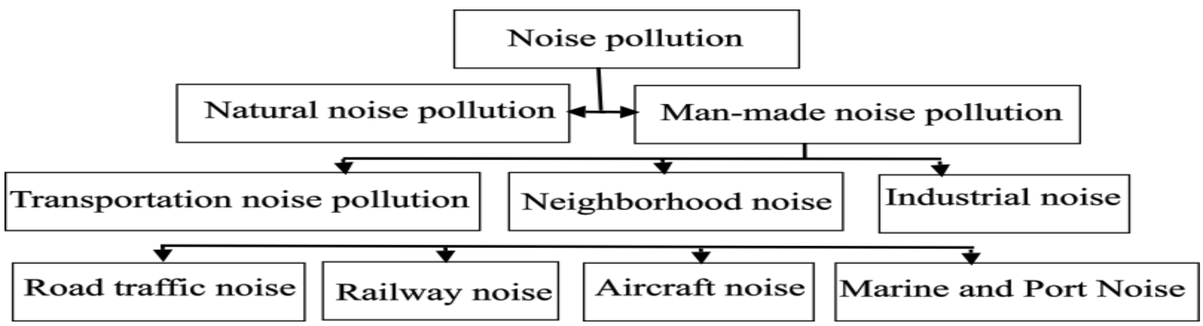

Fig. 1. Types of noise pollution

2. ROAD TRAFFIC NOISE

Road traffic noise contributes 55% of the total transportation noise pollution. The noise produced from the tire screeching, honking, engine, and braking system of a vehicle leads to the vehicular noise pollution [16] [15]. There are other factors such as typeof road, number of heavy vehicles on the road, weather conditions etc. that contribute to the road traffic noise pollution [7]. Table 1 shows the permissible noise limit of traffic noise prescribed by the Central Pollution Control Board, India.

Table 1. Permissible Road Traffic Noise Limit

Time period	Noise limit in India (dB)	
	Daytime	Nighttime
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	50	40

3. RAILWAY NOISE

Railway noise is defined as the unwanted sound generated by vibrations induced due to friction in between track and wheels of rail surfaces, loose connection in between train carriages, sound produced by horn, whistle etc[10]. These vibrations then radiate in the surrounding and propagate through the atmosphere which then arrive at the listener who are the one to determine whether sound is unwanted (i.e., noise) or not. This noise cannot be eliminated but can be reduced by using proper design, rerouting railway tracks and by implementing acoustic barriers [17]. There are several factors that may affect noise produced by railways like train length discrepancies, wheel-rail interaction, track irregularities, weight and speed, bridge crossings, braking and suspension etc. Primarily, Noise pollution caused by railways deteriorating the public health of nearby residents and WHO also warned about its adverse physiological effects on human under the long exposure to the high noise. There are several cases of stress, hearing impairment and cardiac arrests were reported in these areas. Such health-hazardous train noisepollution is specifically problematic in densely crowded towns. In numerous countries, investigating train-related noise has become increasingly crucial. This is primarily driven by a shift from road and air transport to rail for environmental reasons. The train noises exhibit diverse and unpredictable characteristics in terms of their timing, frequency, spatial distribution, and directionality [2]. Additionally, excessive noise pollution poses a severe threat to human health, it becomes necessary to measure peak and off-peak noise levels. Accurate measurements are essential for taking effective actions to mitigate noise pollution originating from railway operations.

Table 2. Permissible railway noise limit

Source of noise	Time period	Noise level (dB)
Wheel-rail interaction, wheel vibrations, rail vibrations, horns, whistles, freight loading, unloading, track joints, crossings.	Daytime	70-85 dB
	Nighttime	60-75 dB

In context, with Table 2, the noise level can vary depending on various factors such as train speed, type of locomotive, track condition. These values are approximate values and may vary for different railway platforms/tracks.

4. AIRCRAFT NOISE

Airlines are the fastest medium for transportation. Aircraft noise is the most significant source of noise pollution. The aircraft noise at certain locations of the airportis inevitable. Airport noise produce a maximum 130 decibel of the sound pressure level, the highest noise pollution level among all the other source of noise pollution such as traffic noise (75-80 dB SPL), Heavy diesel vehicles (85-90 dB SPL), and industrial noise (up to 95 dB). Aircraft noise is certified internationally. It is measured at three points as follows:

1. Take-off: 6.5 km from the start of the roll.
2. Side-line on the runway: 450 meters from the runway.
3. Approach: 2 km from the runway threshold and 120 mhigh.

The aircraft noise limit depends upon the weight of the aircraft and the number of engines (if the number of engines are increased then noise level is also increased). The Union environment ministry notified permissible noise levels at airports. The rules state that busy airports, defined as those with more than 50,000 take-offs and landings per year. The reasons of noise pollution at the Airport are the braking process shortly after touchdown, aircraft engine noise (loading/unloading of luggage & passenger boarding/de- boarding into the aircraft), high speed turbulence over the fuselage of the aircraft and the weather conditions [18].

Table 3. Permissible aircraft noise limit

Time period	Busy Airports		Small Airports	
	Daytime	Nighttime	Daytime	Nighttime
Permissible Noise limit in India (dB)	75	65	65	60

5. MARINE OR PORT NOISE

Marine or port noise pollution is defined as the unwanted sound waves generated by various sources in and around marine environment. This might involve noise from ship engines, marine traffic, propellers of ships, underwater activities etc. These noises propagate through the water and affect both underwater and the costal ecosystem. It is not possible to eliminate marine noise completely but a few mitigation strategies such as quieter ship designs, route adjustment and underwater acoustic barriers can help to reduce its impact on aquatic as well as terrestrial ecosystem. Factors affecting marine noise may include ship size, engine type, hooters near the port, underwater topography, speedwith which ship is moving in the sea [13]. Marine noise pollution is a growing concern due to its noise there is a various ecological and health issues, including stress in marine animals and potential impact on the health of human beings residing near the seaports has been observed [13] . Sometimes, army drills with submarines also impact the underwater life uses of weapons will unbalance the aquatic ecological system. For better understanding, Table 4 shows the primary causes of noise and noise level. These noise levels provide the general range of noise producednear the seaports due to operational activities. However, actual noise levels can vary, and different parameters areresponsible for that such as distance from the source, sensors used to measure noise. Due to the vastness of the ocean, we cannot eliminate the noises but by using several transducing techniques can transform this untapped orunharnessed energy from the oceans.

Table. 4. Marine and port noise limit

Source of noise	Description	Noise level(dB)
Ship Engines	The operation of ship engines and propulsion system.	80-120 dB
Cargo Handling	Loading and unloading of containers and goods.	70-100 dB
Vehicle Traffic	Trucks, forklifts, and other vehicles in the port area.	60-85 dB
Ship Horns	Warning signals emitted by ships during navigation.	100-130 dB
Construction On Activities	Building and maintenance work in and around the port.	80-110 dB
Port Machinery	Cranes, conveyors, and other equipment used in port.	70-100 dB
Port Operations	Operational activities at the port.	60-80 dB

6. MATHEMATICAL MODEL OF TRANSPORTATION NOISE POLLUTION

Noise pollution is the unwanted sound that can be expressed in terms of sound pressure level (SPL). The equivalent SPL, L_p is expressed as follows:

$$L_p=20*\log_{10}(P/P_r) \qquad (1)$$

Here, P is sound pressure (in Pascal) and P_r is the reference sound pressure (20µPa).

A simple mathematical model for transportation noise pollution can be given as follows:

$$N=X+Y\log_{10}(Z)+W*V+E \qquad (2)$$

Here, W, X, and Y are the constants that depend upon the type of transportation noise, N is the noise pollution level (in decibel), Z is the distance from the noise source, V is the velocity of the source(vehicle), F is the other environmental factor. A precise model for transportation noise may depend on the specific transportation scenario, road geometry, noise source type etc.

7. SCOPE OF TRANSPORTATION NOISE FOR ENERGY HARVESTING

Transportation noise pollution has a significant impact on the environment. The transportation noise pollution produced from numerous sources has the potential to get converted it into electrical energy [3]. Harnessing untapped energy from transportation noise pollution can be done by using various transducers like piezoelectric transducer, acoustic transducer, electromagnetic transducer. Figure 2 shows the flow chart of the transportation noise energy harvesting. Acoustic transducers are extensively used to powering and charging devices like sensor nodes, mobiles, and medical devices [4].

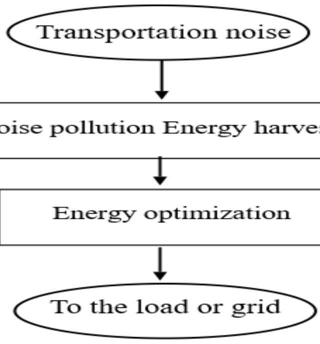

Fig. 2. Transportation noise energy harvesting.

However, the alternating current (AC) generated by acoustic transducer should be converted into direct current (DC)for usage or storage. Therefore, it requires rectifier circuit for the rectification process, which plays a crucial role between the transducer and the storage device [11] [12]. The conventional full-wave bridge rectifier (FBR) is the simplest rectifier circuit but due to the high forward voltage V_f of diodes and ripples in the rectified DC voltage (V_{dc}). FBR circuit become unsuitable and inefficient for many applications [5]. To overcome the abovementioned drawbacksvarious linear and non-linear electronic circuits have been proposed [6]. One example is single stage Bridge-less boost converter (SSBBC) circuit with the implementation of metal oxide semiconductor field effect transistor (MOSFET) proposed in this paper which eliminates the stress in switching techniques and reduces the conversion losses in the rectification process due to the forward voltage of diodes as shown in Fig.3.

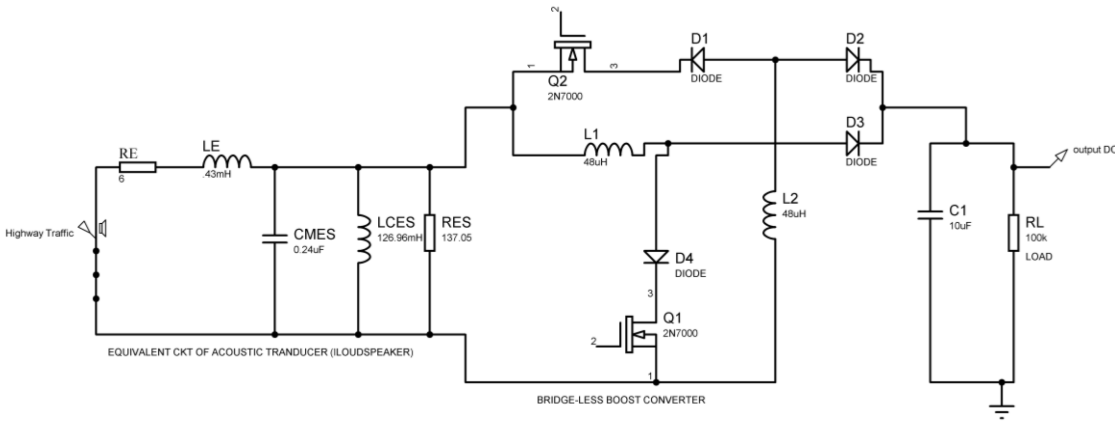

Fig.3. Proposed SSBBC Circuit with Acoustic Transducer

The proposed SSBBC circuit, as illustrated in fig. 3, Comprises an equivalent circuit of an acoustic transducer(loudspeaker) and a Bridge-less boost converter connected to a load. The equivalent circuit of a speaker transforms mechanical parameters into electrical domain to form a circuit that acts exactly as speaker (electrically) [9]. In fig.4, equivalent circuit of loudspeaker with internal parameters are calculated using datasheet. Below are the described parameters of the equivalent circuit:

$\mathbf{R_e}$ = DC resistance of a loudspeaker transducer (ohms)

$\mathbf{L_e}$ = Voice coil inductance measured in milli-Henry (mH)

$\mathbf{C_{mes}}$ = Mass of diaphragm

$\mathbf{L_{ces}}$ = Mechanical damping

$\mathbf{R_{es}}$ = Compliance of the suspension

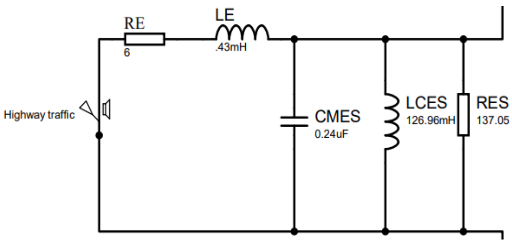

Fig.4. Equivalent circuit of Acoustic Transducer (Loudspeaker)

Furthermore, bridge-less boost converter consists of 2 inductors to reduce the stress on switching process. When the voice coil of speaker is energized by the motion of the coil placed in magnetic field due to the sound wave then emf is induced in the coil [8]. When capacitor, C_1 is fully charged by the voice coil of speaker. During the positive half cycle, switch Q_1 was in on condition and inductor L_1 will get energized by the capacitor C_1. Thus, the inductor current I_{L1} would gradually increase from zero while diodes D_2 and D_3 were in reverse biased. At the end of the positive half cycle, switch Q_1 was in a turned off condition. The energized inductor L_1 freewheeled via D_3 and charge the load capacitor C_L until inductor I_{L1} current becomes zero and feed load resistor R_L. During the negative half cycle, switch Q_2 was in on condition and inductor L_2 will get energized by the capacitor C_1. Thus, the inductor current I_{L2}would gradually increase from zero while diodes D_2 and D_3 were in reverse biased. At the end of the positive half cycle, switch Q_2 was in a turned off condition. The energized inductor L_2 freewheeled via D_2 and charge load capacitor C_L until inductor I_{L1} current becomes zero and feed load resistor R_L.

8. SIMULATIONS

The waveform Simulated by SSBBC circuit using PROTEUS software are described within the context of Fig.5. It should be noted that an ideal source with negligible source impedance was adopted in PROTEUS. Thus, real time noise signals have been analyzed with the converter circuit and investigated the noise characteristics of several environmental sources including highway traffic, aircraft launchpad operations, railway tracks and market activities. Furthermore, simulations were conducted with inductor values 20μH along with load resistors of 100kΩ to analyze their impact on circuit performance as shown in Table 5.

Table 5: Various Noise Sources and Output Voltage across Proposed SSBBC Circuit

Source	NoiseInput (dB)	VoltageOutput (mV)	Frequency (Hz)	Output Power (μW)
Highway Traffic	70-75	198	100-1000	392
RailwayTracks	80-100	222	20-1000	400
Aircraft Launchpad	110-125	325	1000-3500	1052
Market Activities	50-60	28	50-500	37.5

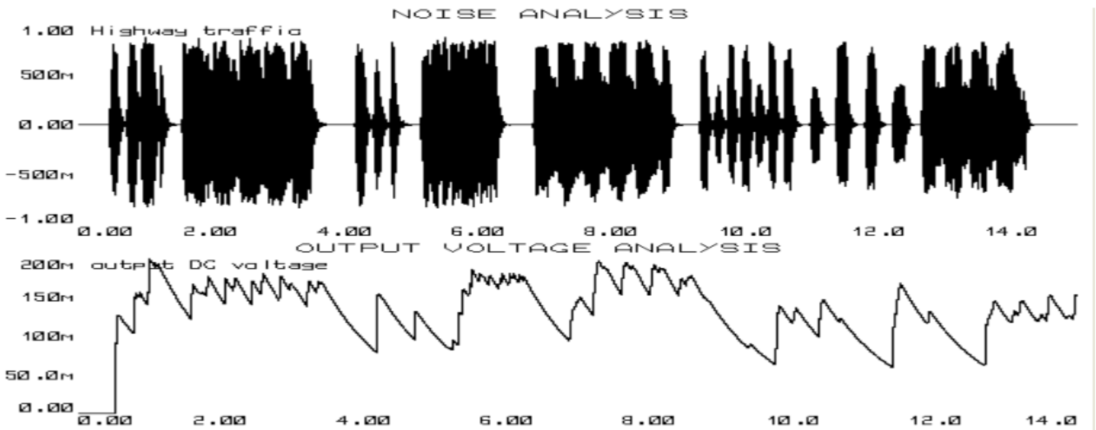

Fig 5. Simulation result for Highway Traffic

9. RESULTS AND DISCUSSUION

This study investigates the performance of a circuit under different values of inductors and load resistors, while also examining the impact of various environmental factors such as highway traffic, railway traffic, and aircraft launching operations. Two distinct inductor values, 20μH and 48μH, are tested alongside three different load resistors: 100kΩ, 660kΩ, and 330kΩ as shown in Table 6 and Table 7. Proposed SSBBC circuit yields best results with 48μH inductor with maximum power of 400μW for highway noise, 237.16μW for railway noise and for aircraft launchpad operations proposed circuit yields better results on 20μH with maximum output power of 1052.64μW.

Table 6. Results of SSBBC Circuit with Inductor Value 20μH

Noise Source	Noise input (dB)	Load Resistor (Ω)	Output voltage (mV)	Output power (μW)
Highway Traffic	70-75	100k	198	390.04
		330k	210	134
		660k	222	74.2
Railway Tracks	80-100	100k	150	225
		330k	150	68.2
		660k	155	36.4
Aircraft launchpad	110-125	100k	324	1052.64
		330k	324	318.75
		660k	323	157.91

Table 7. Results of SSBBC Circuit with Inductor Value 48μH

Noise Source	Noise input (dB)	Load Resistor (Ω)	Output voltage (mV)	Output power (μW)
Highway Traffic	70-75	100k	200	400
		330k	211	135
		660k	222	74.7
Railway Tracks	80-100	100k	154	237.16
		330k	151	69.1
		660k	155	36.4
Aircraft launchpad	110-125	100k	323	1043.29
		330k	324	318.175
		660k	325	159.81

10. CONCLUSION

Transportation noise is one of the main cause of noise pollution. The noise energy produced by transportation sources has a potential to convert it into electrical signals which will help in mitigating noise pollution as well as reducing carbon footprints otherwise all that energy goes to waste and dissipate in the atmosphere. The modelling and simulation have been done for conversion of noise / sound into electricity which shows the generation of electricity that can be used for glowing LED. This sustainable approach can help to mitigate noise pollution while simultaneously harnessing untapped resources can be used in various applications such as powering up surveillance cameras in remote areas, and charging micro electronic devices etc. The transportation noise can be used specifically for illuminating LEDs for blind spots.

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