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Design and Development of Army Shoes with Integrated Electricity Generator and Sensor System

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***Abstract*—**Soldiers on foot rely on radios, navigation aids, and sensors powered by batteries, and each spare cell adds to the load carried and to resupply needs. This paper presents the design of a boot-integrated system that recovers part of the mechanical energy of walking and combines it with wearable sensing. Piezoelectric transducers under the heel and forefoot convert footfall pressure into an alternating voltage, which is rectified and conditioned before storage in a rechargeable lithium-ion or lithium-polymer cell, with an optional supercapacitor as a buffer. An Arduino Nano or ESP32 controller reads an MPU6050 inertial sensor and a pressure sensor, and an LED indicates when the harvested voltage crosses a threshold; GPS, temperature sensing, and wireless telemetry are optional extensions. An electromagnetic generator is considered only as an alternative. The paper describes the subsystems, the separate energy and data paths, and the supplied sensor-reading program, and lists assumptions to be checked before the code is used with specific hardware. Quantitative performance has not been measured, so a test plan for harvested energy, storage, sensor consistency, and durability is proposed. The design is a documented starting point for a prototype that supplements, rather than replaces, conventional power sources.

***Keywords*—**Energy harvesting, piezoelectric transducer, smart footwear, embedded sensors, power management, wearable technology, MPU6050, military electronics.

I. INTRODUCTION

Personnel working away from a fixed power supply carry a growing set of electronic devices: radios, navigation aids, lights and, increasingly, wearable sensors. Each of them depends on a battery that must either be carried or resupplied. Spare cells add mass that is borne on foot, and in remote terrain the options for recharging are limited; solar charging, for instance, depends on daylight and weather. Reducing the number of batteries that must be carried, even by a small fraction, is therefore a practical engineering goal.

Walking is a repeatable source of mechanical energy. At every step, the heel compresses the sole and the forefoot bends as the foot rolls off, and most of this work is dissipated as heat. Recovering a little of it has interested researchers for some time, and the surveys of human-powered and wearable energy harvesting in [1, 2] place the shoe among the more promising body locations.

Piezoelectric inserts mounted in shoes were demonstrated early on [3], and the piezoelectric footwear literature has since been reviewed in detail [4]. The power that such harvesters deliver is modest, typically in the milliwatt range or below [5, 6], so they are better suited to supplying low-power electronics than to running power-hungry equipment.

A shoe can also act as a sensing platform. Inertial and pressure sensors worn on the foot are widely used for gait analysis [7], and a shoe that already carries a small energy source has a natural place for such sensors. The project reported here therefore combines two functions in one piece of footwear: harvesting of footfall energy, and sensor-assisted monitoring of movement and foot loading, with optional location and temperature sensing.

The problem addressed is how to arrange these two functions so that the harvested energy is stored and delivered safely, the sensing electronics are supplied from a regulated source, and the claims made for the system stay within what can be shown. The contribution of this paper is a documented design rather than a measured result. It sets out (i) a system architecture that keeps the energy path and the data path distinct, (ii) the role of each component and whether it is core or optional, (iii) a critical review of the supplied sensor-acquisition program, and (iv) a test methodology for the measurements the project still needs.

II. PROBLEM STATEMENT AND OBJECTIVES

Four engineering problems motivate the work. First, portable electronics depend on conventional charging, which assumes access to a charging source. Second, carrying spare batteries increases the weight on the person and creates a resupply requirement. Third, opportunities to recharge in remote locations are limited and unpredictable. Fourth, continuous wearable sensing needs a local power source, so harvesting and sensing are more useful together than apart: even a small, steady supplement of energy may keep a low-duty-cycle sensor node running longer between charges.

The objectives of the project, restated so that each can be checked, are the following:

O1. Design a sole-integrated generator that converts walking or running loads into electrical energy, with piezoelectric transducers at the heel and forefoot as the primary mechanism.

O2. Define a power path that rectifies, conditions, and stores the generated energy in a rechargeable lithium-ion or lithium-polymer cell, with an optional supercapacitor, and delivers a regulated supply to the electronics.

O3. Integrate an MPU6050 inertial sensor and a pressure sensor with an Arduino Nano or ESP32 controller, and acquire their readings together with the piezoelectric voltage.

O4. Provide status indication through an LED, and specify optional functions (GPS, temperature sensing, USB output, and Bluetooth or Wi-Fi telemetry) as extensions.

O5. Specify a procedure for evaluating the feasibility, efficiency, and durability of the system under practical conditions.

The paper is organized as follows: Section III reviews related work, Section IV details proposed methodology, Section V explains system architecture, Section VI covers implementation, Section VII presents experimental methods, Section VIII analyzes expected results, Section IX details applications, Section X covers advantages, limitations, and future scope, and Section XI concludes the paper.

III. LITERATURE REVIEW

A. Piezoelectric Energy Harvesting in Footwear

Shenck and Paradiso [3] described shoe-mounted piezoelectric harvesters that exploit the two places where a shoe is mechanically stressed: a flexible polyvinylidene fluoride (PVDF) stave under the forefoot that responds to sole bending, and a reinforced lead zirconate titanate (PZT) dimorph at the heel that responds to heel strike. They also used the harvested energy to power a radio-frequency identification tag. Documentation from the same group [5] reports peak powers of 20 to 80 mW and averages of 1 to 2 mW during brisk walking for early inserts of this kind, and it identifies the real difficulty: the source is a high-voltage, low-frequency, micro-power capacitive source, for which simply discharging into a load is lossy.

Zhao et al. [4] reviewed the field more than two decades later. They organise the energy flow from walking to the load into four steps (capturing mechanical energy in the deformed shoe, transferring it into the piezoelectric material, converting it to electrical energy, and delivering it to a circuit) and classify the harvester structures into flat-plate, curved, cantilever, and flexural types. They also note that walking occurs at about 1 Hz, far below the resonant frequency of the piezoelectric elements, so that the elements behave essentially as capacitors. For the present project, this has two consequences: the heel and forefoot are the sensible mounting sites, and the conditioning electronics have to be designed for a capacitive, intermittent source rather than for a conventional voltage source.

B. Electromagnetic Mechanisms

Electromagnetic generators use the relative motion of a magnet and a coil. Saha et al. [6] built a magnet-spring generator and tested it on a shaker and on a person walking and running slowly, obtaining between 300 µW and 2.5 mW. The device was body-worn rather than shoe-mounted, which matters: a moving magnet needs room to travel, and a thin sole offers little of it. In general, electromagnetic generators deliver a low voltage from a low-impedance coil, while piezoelectric elements deliver a high voltage from a high-impedance source, so the two call for different conditioning. For these reasons, the coil-and-magnet approach mentioned in the project report is treated here only as an alternative, and the piezoelectric transducer remains the primary mechanism.

C. Power Conditioning and Energy Storage

Ottman et al. [8] studied how to move energy from a mechanically excited piezoelectric element into a battery. Their circuit combines a rectifier with an output capacitor, a battery, and a switch-mode DC–DC converter under adaptive control, and the converter increased the power transferred by more than 400% compared with the same circuit without it. The element in that work was vibration-driven rather than footfall-driven, but the lesson carries over: rectifying a piezoelectric source straight into a battery or a regulator leaves much of the available energy unused. The maximum power point tracking (MPPT)-style control mentioned in the project slides is of this kind and is treated here as a proposed enhancement.

Surveys of energy harvesting [1] also stress the demand side: dynamic voltage and clock scaling, and wake-up procedures that keep the electronics mostly inactive, extend operation as much as a better source does. For intermittent harvested power, storage is normally split between a small, fast buffer such as a supercapacitor and a larger rechargeable cell; the project adopts that arrangement, with the supercapacitor optional.

D. Wearable Sensing and Microcontroller-Based Monitoring

Tao et al. [7] reviewed wearable sensors for gait analysis, including accelerometers, gyroscopes and force sensors worn on the foot or waist, and summarised applications in sports, rehabilitation and clinical diagnosis. The MPU-6050 [9] combines a three-axis accelerometer and a three-axis gyroscope with 16-bit analogue-to-digital converters (ADC) and an I²C interface, which makes it a common choice for low-cost motion sensing. On the controller side, the ESP32 offers integrated Wi-Fi and Bluetooth and a 12-bit ADC [10], while the Arduino Nano is simpler and has no radio; the choice is a trade-off between connectivity and energy use that is taken up in Sec. VIII.

E. Defence-Oriented Work

The most directly relevant public document found is a technical report on piezoelectric energy for soldier systems [11], which describes a three-year effort in which four proof-of-concept heel-strike units, each a small piezoelectric generator in the form of a combat-boot heel, were built and then tested and evaluated. A more recent conference abstract [12] proposes a footstep-powered piezoelectric system for military use in jungle terrain so that soldiers can recharge battery backups. Only the abstract was available to the authors, so its results are not discussed. Public documentation of footwear harvesters in routine operational use was not found in the sources reviewed, and no such use is claimed here.

TABLE I. SUMMARY OF RELATED WORK DISCUSSED

Ref.	Contribution	Relevance to this Project
[4]	Review of piezoelectric footwear harvesters; four structure types	Heel and forefoot placement; source treated as capacitive
[3]	PVDF stave and PZT dimorph shoe inserts; self-powered tag	Early demonstration of the two mounting sites
[5]	Early insert outputs; conditioning problem for a capacitive source	Order of magnitude of power; need for a conditioning stage
[8]	Rectifier, battery and adaptive DC–DC converter (>400% gain)	Supports a DC–DC stage before storage
[6]	Body-worn electromagnetic generator; 300 µW to 2.5 mW	Alternative mechanism; not shoe-mounted
[11]	Heel-strike units for combat-boot heels; tested	Defence context for the footwear approach
[7]	Review of wearable sensors for gait analysis	Basis for inertial and pressure sensing

Taken together, the reviewed work shows that footwear harvesters, conditioning circuits and wearable sensors have each been studied, but mostly separately. This project assembles them into one low-cost design built around common modules (a piezoelectric element, an MPU6050 and an Arduino or ESP32 board). Whether such a combined shoe can sustain even a small sensing duty cycle from footfall energy alone is the question it is set up to examine.

IV. PROPOSED METHODOLOGY AND SYSTEM DESIGN

The system consists of an energy-harvesting unit, a power-conditioning and storage chain, and a sensor-and-control unit housed in the shoe sole and casing. Table II lists the components named in the project report and slides and marks whether each is part of the core design, is optional, or is only an alternative. The final transducer part, the pressure-sensor type, and the choice between the Arduino Nano and the ESP32 are not fixed in the documentation.

TABLE II. COMPONENTS, FUNCTIONS, AND DESIGN STATUS

Component	Function	Status
Piezoelectric transducers (heel, forefoot)	Convert sole deformation to AC voltage	Core
Coil and magnet	Induction-based generation	Alternative
Diode rectifier	AC to DC conversion	Core
Voltage regulator	Stable supply for electronics	Core
MPPT-style DC–DC stage	Improved energy transfer	Proposed
Li-ion / Li-Po cell (3.7 V)	Stores harvested energy	Core
Supercapacitor	Short-term buffer	Optional
Arduino Nano or ESP32	Sensor acquisition and control	Core
MPU6050	Acceleration & rotation sensing	Core
Pressure sensor	Foot-impact measurement	Core
Temperature sensor, GPS	Environment and location	Optional
LED indicator	Status indication	Core
USB port	Output to small devices	Optional
Bluetooth / Wi-Fi	Wireless telemetry	Optional
Sole insert, foam, casing	Mounting and protection	Core

A. Energy Harvesting Unit

The piezoelectric transducers are placed at the pressure-bearing regions of the sole, the heel and the toe. When the foot loads the sole, the material is strained and, through the direct piezoelectric effect, develops a charge and hence a voltage across its electrodes. Because the sole is loaded and then released at every step, the output swings in polarity and is alternating or pulsed, and its amplitude depends on the applied force, the strain rate, and the electrical load. Ceramic elements such as PZT give higher output but are brittle, whereas PVDF film is flexible but weaker; shoe prototypes have used both [3], and the slides mention high-strain ceramics or PVDF films without fixing the choice.

The electromagnetic alternative, a coil and magnet in relative motion, is described in the report but is not the mechanism assumed by the supplied program, which reads a piezoelectric input. It is therefore treated as an alternative that would need its own conditioning stage (Sec. III-B).

B. Power Conditioning

The raw output of the transducers cannot be applied directly to a battery or a regulator. It is alternating, its peak voltage varies from step to step, and it can exceed the safe input range of downstream components during a hard heel strike. The proposed chain therefore begins with a diode bridge that rectifies the output into a smoothing capacitor, which accumulates energy between steps. Low forward-drop diodes are preferable, since a conventional diode drop consumes a significant fraction of a source that may only reach a few volts. A clamp or transient suppressor at the input protects against voltage spikes.

A regulator then supplies a stable rail to the controller and sensors. A linear regulator alone is a poor match for this source, because it cannot control how much energy is drawn from the transducer; a switch-mode DC–DC stage, as in [8], is the better arrangement. MPPT-style control, which adjusts the operating point of that stage to extract more energy, appears in the project slides and is considered here only as a proposed enhancement, since no implementation is documented.

C. Energy Storage

Energy is stored in a rechargeable lithium-ion or lithium-polymer cell, nominally 3.7 V, with an optional supercapacitor as a buffer for the short pulses of the harvester. A lithium cell must be charged within defined voltage and current limits and protected against overcharge, deep discharge, overcurrent, and short circuit. A rectifier and a regulator do not by themselves provide that safety. A dedicated charge-management stage and a protection circuit, ideally one designed for very low input power, are needed, and they must be chosen with the cell and the enclosure in mind. A supercapacitor has a low voltage rating per cell, so any stack of cells needs voltage balancing or a converter. These parts are part of the proposed design and are not yet specified.

D. Controller and Sensors

The controller, an Arduino Nano or an ESP32, reads the sensors, applies simple processing, and drives the status output. The two boards differ in ways that matter for the circuit and the code: the Nano uses 5 V logic and a 10-bit ADC, whereas the ESP32 uses 3.3 V logic, a 12-bit ADC, and built-in wireless [10]. The MPU6050 [9] provides three-axis acceleration and rotation over I²C and is the basis for step and activity detection [7]. A pressure sensor measures foot-impact intensity. A GPS module and a temperature sensor are listed as optional; the supplied program does not read them, so they are not treated as implemented.

According to the report, the controller would also monitor battery voltage, apply charging-control logic, and prioritise the supply of the sensors over external charging. These functions belong to the proposed design. Duty-cycling and sleep states of the kind noted in [1] would be needed so that the electronics do not consume more than the shoe harvests.

E. Output and Communication

The LED is the simplest output. In the supplied program, it lights when the sampled piezoelectric voltage exceeds a threshold. The report additionally describes a USB port for charging small devices and Bluetooth or Wi-Fi transfer of sensor data to a handheld unit. A USB output would need a boost converter, a current limit, and logic to enable it only when the stored energy allows. Wireless telemetry should be sent in short bursts, since radio activity is likely to dominate the energy budget. No claim is made that harvested energy can run military radios, GPS equipment, or other power-hungry devices continuously.

V. SYSTEM ARCHITECTURE AND WORKING PRINCIPLE

Figure 1 shows the proposed architecture. It separates two paths that the linear block diagram in the project report presents as one chain. The energy path (solid arrows) runs from footfall through the transducers, the rectifier and protection stage, an optional DC–DC stage and the storage element to a regulated rail. The data path (dotted arrows) runs from the sensors to the controller and from the controller to the outputs. The two meet only where the controller is supplied from the rail, and where a scaled copy of the piezoelectric voltage is fed to an ADC input for monitoring, as the supplied program does.



Fig. 1. Proposed system architecture showing the energy path and the data path. Dashed blocks are optional or proposed.

In operation, the following sequence takes place:

(1) During walking or running, heel strike and forefoot bending deform the transducers.

(2) The transducers produce an alternating or pulsed voltage.

(3) The rectifier and smoothing capacitor convert this to a unidirectional voltage, and the protection stage limits excursions.

(4) A DC–DC or charge-control stage, proposed but not yet specified, moves the accumulated energy into the lithium cell, with the supercapacitor optionally smoothing the pulses.

(5) The regulator provides a stable rail from the cell for the controller, the sensors, and the LED.

(6) The controller samples the sensors and the monitored voltage and, in the full design, manages communication.

The controller and sensors are shown as loads on the regulated rail. This is a design choice, not a result of the electrical path: the sensors need not be supplied through the harvested-energy chain in the order shown in the report, and a separate small cell for the electronics would be a valid alternative. The arrangement in Fig. 1 should be confirmed against the actual circuit.

VI. HARDWARE AND SOFTWARE IMPLEMENTATION

A. Hardware

The hardware comprises the components in Table II, mounted on a PCB or perfboard and housed in a protective casing within the sole. The report specifies a modified army-shoe sole as the base, shock-absorbing gel or foam to protect the components and keep the shoe comfortable, and a waterproof, impact-resistant casing for the electronics and battery. No drawings, dimensions, or photographs of an assembled shoe are included in the documentation, so the mechanical integration is described here only at the level of intent.

B. Embedded Program

The supplied program is written for the Arduino environment and uses the Wire library and an MPU6050 library. In setup(), it opens the serial port at 9600 baud, starts I²C, initialises the MPU6050 and configures the LED pin. In each pass of loop(), it does four things:

1) Reads the piezoelectric input on A0 and converts the count to a voltage with:

$$V = (N \times 5.0) / 1023 \quad (1)$$

where N is the ADC count.

2) Switches the LED on if V exceeds 1.0 V.

3) Reads the pressure sensor on A1 and prints the raw count.

4) Reads raw X, Y, and Z acceleration from MPU6050, prints all values to the serial monitor, and waits one second.

C. Review of the Program and Its Assumptions

The program is a sensor-reading and demonstration sketch. It is not a complete implementation of the system described in the report. Table III compares the functions described in the report with what the code contains.

TABLE III. FUNCTIONS DESCRIBED IN REPORT VS. SUPPLIED PROGRAM

Function	In the Supplied Program
Piezoelectric voltage reading	Yes: one sample per second
Pressure sensor reading	Yes: raw ADC count
MPU6050 acceleration	Yes: raw counts, unscaled
MPU6050 rotation (gyroscope)	No
LED voltage-threshold indication	Yes: 1.0 V on one sample
Step counting, speed, activity	No
Battery monitoring, charge control	No
USB output control	No
GPS and temperature reading	No
Bluetooth / Wi-Fi telemetry	No
Data logging	Serial print only
Sleep or duty-cycling	No (blocking delay)

Several assumptions should be checked before the code is used with specific hardware:

Board and ADC scaling: Equation (1) is correct for a 5 V board with a 10-bit converter such as the Arduino Nano. On an ESP32, the converter is 12-bit, the pin tolerates 3.3 V, and the usable range depends on the attenuation setting [10], so the same expression would give a wrong voltage. The labels A0 and A1 are Nano names; ESP32 boards use GPIO numbers. GPIO9 is also commonly reserved for the module's flash memory on ESP32 boards and should not be used for the LED there.

Input protection: A piezoelectric element driven by a heel strike produces voltages that can swing negative and exceed the supply rail. If the element is connected directly to an analogue input, which the sketch appears to assume, it needs at least a series resistor, a clamp and a divider, or a rectifier and smoothing capacitor, to avoid damaging the pin.

Voltage is not power: The value printed as "Generated Voltage" is an instantaneous voltage at a high-impedance node, and it depends on the load, here the ADC input. It is not a measurement of usable harvested power. Power requires the voltage and the current delivered to a defined load (Sec. VII).

Sampling rate: One sample per second is far too slow to capture a heel-strike pulse, which lasts a fraction of a second, and the single sample may fall between pulses. Peak detection in hardware, or sampling at a much higher rate, would be needed for any quantitative reading.

Threshold logic: The 1.0 V threshold is arbitrary and one sample high only means that voltage was present at that instant. The LED therefore does not indicate charging or battery state, although the report describes it that way.

Accelerometer scaling and range: The values are raw 16-bit counts. At the default ±2 g range, the sensitivity is 16384 counts per g [9], and impacts at the foot may exceed that range, so a wider range should be considered. The Arduino Nano uses A4 and A5 for I²C, so these pins are not available for analogue inputs, and the ESP32 uses different default pins. The bare MPU-6050 is a 3.3 V-class device, so logic-level compatibility with a 5 V board should be confirmed for the breakout board used.

VII. EXPERIMENTAL SETUP AND EVALUATION METHOD

A. Current Status

The documentation supplied for this work contains the design, the component list and the sensor-reading program. It contains no photographs or drawings of an assembled shoe, no test conditions, and no recorded measurements. The paper therefore reports no experimental data. The following evaluation methodology is proposed; it describes tests that would be carried out.

B. Proposed Evaluation Methodology

The first need is a measurement of the harvester itself. The transducer output would be recorded on a data logger or oscilloscope while a known load is applied, either by a mechanical rig that imitates a heel strike or by a person walking on a treadmill. Because a piezoelectric element is a capacitive source, the output depends strongly on the load resistance, so the load would be varied to find the value at which the delivered power peaks. For a resistive load R, the average power over a period T and the energy over an interval are:

$$P = (1 / T) \int v(t)^2 / R \, dt \quad (2)$$

$$E = \int v(t) \, i(t) \, dt \quad (3)$$

where v and i are the voltage and current at the load. The energy per step is E divided by the number of steps in the interval, and the net energy balance is the harvested energy minus the energy consumed by the electronics over the same period. Table IV lists the proposed tests.

TABLE IV. PROPOSED EXPERIMENTAL TESTS

Test	Measurement & Condition	Criterion
Harvested voltage and current	Load sweep; heel and forefoot elements separately	Load of peak power
Energy over a walk	Count steps; integrate $v \times i$, Eq. (3)	Energy per step
Speed and pressure	Several walking speeds and body loads, repeated trials	Mean and spread
Sensor consistency	Repeated steps against a reference count	Agreement with reference
Storage & regulation	Rail voltage and ripple under changing load	Rail within its limits
Charging & protection	Charge-limit and cut-off behaviour with a safe test cell	Limits respected
Shoe-level checks	Mass, comfort, impact, moisture ingress	Team-defined limits

Each test would be repeated several times per condition, for example at least five, so that a mean and a spread can be reported rather than a single reading. The acceptance criteria in the third column are to be fixed by the team before testing. The shoe-level checks should be carried out with the electronics and cell enclosed, since the energy performance means little if the shoe is uncomfortable, too heavy or not sealed.

VIII. RESULTS AND DISCUSSION

A. Status of Results

No quantitative performance has been established in the current documentation. This paper therefore presents no efficiency figure, charging time, battery life or accuracy value, and it should not be read as evidence that the shoe delivers any particular power. What follows is a discussion of expected behaviour and of the trade-offs that measurement will have to resolve.

B. Expected Behaviour and Energy Scale

The order of magnitude is the key issue. Early shoe inserts averaged 1 to 2 mW in brisk walking [5]. As an illustration only, at 1 mW the energy gathered in one hour is 1 mW × 3600 s = 3.6 J, about 1 mWh. A 1000 mAh cell at 3.7 V stores about 3.7 Wh, several thousand times as much. A harvester of that scale could not charge a radio or phone battery in a useful time, and its realistic role is to offset a small, carefully managed load such as a microcontroller and a few sensors. This is an arithmetic illustration, not a prediction for this design.

Two further points follow. Conversion losses in the rectifier, the DC–DC stage, and the charge controller reduce what reaches the cell, and the benefit of an adaptive stage reported in [8] indicates that these losses can be large. A one-second sampling loop and a Wi-Fi or Bluetooth radio left on would each draw more than a small harvester supplies, so duty-cycling and burst telemetry are requirements.

C. Design Trade-Offs

Table V lists the main trade-offs and the measurement that would resolve each. They are expectations from engineering principles and from the literature, not outcomes of this project.

TABLE V. DESIGN TRADE-OFFS AND RESOLUTION METRICS

Trade-off	Why it Matters	Measurement
Energy per step vs. demand	Sets supported loads	Net energy balance
Durability vs. flexibility	Brittle ceramics vs. weaker film	Cycling test; drift
Electronics vs. shoe weight	Mass carried on foot	Finished shoe mass
Comfort vs. placement	Rigid parts under foot	User comfort trial
Cell capacity vs. harvest	Large cell fills slowly	Charge rate vs. capacity
Wireless vs. energy use	Radio dominates draw	Current per mode

IX. APPLICATIONS

The following are potential applications:

Military and defence personnel monitoring: Foot-mounted sensing of movement and loading, with supplementary power, could support monitoring of dismounted personnel, as framed in [11].

Remote-area field operations: Teams working far from a fixed supply could use a shoe-mounted source to extend the time a low-power sensor node runs between charges.

Emergency and rescue personnel: The same arrangement could provide activity and location data for rescue teams, although the location function depends on the optional GPS module.

Low-power wearable sensing: Any wearable node with a small duty cycle is a candidate for a footfall-powered supplement.

Activity and gait monitoring: Inertial and pressure sensing in the shoe is directly relevant to gait analysis [7].

X. ADVANTAGES, LIMITATIONS, AND FUTURE SCOPE

A. Potential Advantages

The main potential advantage is supplementary energy generated by an action the wearer performs anyway, which may reduce dependence on external charging for selected low-power functions. Combining generation with sensing in footwear also avoids a separate wearable device.

B. Limitations

The harvested output varies with walking speed, load, and gait, and conversion losses reduce what is stored. Space in a shoe is limited, so transducers, electronics and a cell must fit without harming comfort. Durability under repeated loading, waterproofing, and maintenance are open concerns, and a lithium cell in footwear raises safety issues.

C. Future Scope

Future work includes building and optimising a prototype, controlled performance testing as in Sec. VII, better transducer placement, lower-power electronics, improved charge control and storage management, durability testing, and integration with a suitable monitoring interface.

XI. CONCLUSION

This paper has presented the design of army footwear combining piezoelectric energy harvesting with an inertial and pressure sensing system. The architecture separates the energy path from the data path, and components are classed as core, optional, or alternative. A review of the supplied program found that it reads piezoelectric voltage, a pressure sensor, and MPU6050 acceleration, but does not implement charging control, GPS, temperature sensing, step counting or wireless telemetry. The potential contribution is a documented starting point for a prototype that supplements conventional power for low-power electronics.

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BIOGRAPHIES



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