

Research Article

Analog Multimodal Device for Early Neuroischemic Diabetic Foot Screening

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Abstract

Diabetic foot disease is one of the most severe complications of diabetes mellitus due to its strong association with ulceration, infection, lower-limb amputation, and increased mortality. In the Dominican Republic and the Caribbean, this burden is further intensified by limited access to early screening technologies and the need for robust, field-deployable solutions adapted to resource-constrained healthcare environments. The objective of this study is to propose a fully analog, discrete-electronics screening device for early neuroischemic diabetic-foot risk assessment. The proposed system integrates two complementary physiological biomarkers: bilateral plantar thermal asymmetry, as an indicator of localized inflammatory stress, and post-occlusive microvascular reactivity, assessed through hyperemic time-to-peak using reflective photoplethysmography. The architecture is based on a hardware-only design that eliminates the need for software, microcontrollers, or digital signal processing, and includes multisite plantar temperature sensing, optical perfusion measurement with synchronous demodulation, a controlled vascular occlusion module, and comparator-based risk classification. This design enables deterministic behavior, direct signal traceability, and local interpretability, which are essential for screening applications in low-infrastructure settings. The main contribution of this work lies in the integration of inflammatory and vascular physiological domains within a single discrete-electronics platform. Unlike existing approaches that rely on digitally mediated systems, the proposed method provides a transparent and resilient alternative for early screening. The study is presented as a design-and-rationale framework with a defined validation pathway, providing a foundation for prototype development, experimental validation, and potential clinical application.

Keywords

Diabetic Foot, Photoplethysmography, Reactive Hyperemia, Microvascular Dysfunction

1. Introduction

Diabetes mellitus remains one of the most consequential chronic diseases worldwide, particularly because of its vascular, neurological, and wound-healing complications. In North America and the Caribbean, the burden of diabetes remains

among the highest reported by the International Diabetes Federation, while regional public-health profiles continue to identify diabetes as a major contributor to morbidity, disability, and long-term health-system strain in the Dominican Republic

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Received: 26 April 2026; Accepted: 8 May 2026; Published: 19 May 2026



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and across the Americas [13, 25-27].

Among diabetes-related complications, diabetic foot disease occupies a particularly severe position because it is closely associated with recurrent ulceration, infection, hospitalization, lower-extremity amputation, and excess mortality. It should therefore be understood not as an isolated wound event, but as a chronic and recurrent manifestation of systemic metabolic, vascular, and neuropathic deterioration [3].

This problem is especially important in the Caribbean context. Regional studies have documented substantial inpatient burden, frequent foot complications, and clinically significant amputation risk across multiple territories, while in the Dominican Republic peripheral arterial disease among people with diabetes has also been reported as a relevant vascular concern [18, 23, 33].

Early risk stratification remains a major unmet need in diabetic-foot prevention. Plantar temperature monitoring has demonstrated preventive utility and has been incorporated into contemporary high-risk diabetic-foot frameworks. Nevertheless, temperature alone does not adequately represent local vascular reserve, tissue reperfusion behavior, or the functional capacity of the microcirculation to respond to transient ischemic stress [8, 17].

The current technology landscape reflects this fragmentation. Existing diabetic-foot systems frequently focus on one of

several partially overlapping domains: plantar temperature monitoring, pressure mapping, connected wearables, smart socks, optical perfusion tools, or digitally integrated remote-monitoring platforms. While these technologies are important and often clinically promising, they are typically embedded in software-dependent ecosystems, rely on microcontrollers or digital processing, or assume a level of maintenance and infrastructure that may not be consistently available in resource-constrained settings [6, 21, 22, 30].

At the same time, discrete-electronics approaches remain relevant in biomedical engineering where reliability, direct verifiability, deterministic operation, and technological resilience are required [20]. Against this background, this manuscript proposes a fully analog screening device integrating thermal asymmetry and microvascular reactivity within a software-free architecture. Previous studies have explored various aspects of diabetic foot monitoring, including photoplethysmography-based physiological measurements [2], advances in sensing technologies [7, 9], and epidemiological and clinical perspectives in different populations [10-12, 14, 19]. These contributions highlight both the complexity of diabetic foot pathology and the need for integrated screening approaches.

Tabla comparativa del estado del arte

Table 1. Comparative positioning of the proposed analog discrete screening device relative to representative diabetic-foot monitoring approaches.

Approach / Technology Type	Main Physiological Variable(s)	Typical Technological Dependency	Active Vascular Challenge	Local Standalone Interpretation	Suitability for Low-Infrastructure Settings	Main Limitation
Remote plantar temperature monitoring socks	Temperature	Embedded electronics, digital logging, often app/platform support	No	Usually limited	Moderate	Temperature-only approach
Smart insoles / connected plantar platforms	Pressure, temperature, activity	Microcontroller-based, digital processing, connectivity	No	Variable	Moderate to low	Higher complexity and maintenance burden
Infrared thermography systems	Surface temperature mapping	Imaging hardware, digital processing, interpretation software	No	Limited without trained analysis	Low to moderate	Higher cost and weaker portability
Optical perfusion systems	Perfusion / hemodynamics	Often digitally processed optical instrumentation	Sometimes	Rarely	Low to moderate	Complexity and cost
Multifactorial digital diabetic-foot platforms	Temperature, pressure, adherence, activity	Strong software and platform dependence	Usually no	Rarely	Low in constrained settings	High ecosystem dependence
Proposed analog	Thermal asymmetry	Discrete analog electronics, no	Yes	Yes	High	Requires experimental

Approach / Technology Type	Main Physiological Variable(s)	Typical Technological Dependency	Active Vascular Challenge	Local Standalone Interpretation	Suitability for Low-Infrastructure Settings	Main Limitation
discrete multi-modal device	+ post-occlusive hyperemic time-to-peak	software, no microcontroller				validation and threshold calibration

In order to position the proposed device more clearly within the diabetic-foot technology landscape, representative existing approaches can be compared across physiological target, technological dependency, interpretability, and translational suitability. The purpose of this comparison is not to deny the value of digitally mediated systems, but to clarify the distinct niche occupied by the present hardware-first, software-independent architecture

2. Conceptual and Physiological Rationale

2.1. Multimodal Nature of Diabetic Foot Risk

Neuroischemic diabetic foot arises from combined neuropathic, vascular, and inflammatory mechanisms. A meaningful screening system should therefore integrate multiple physiological domains rather than relying on a single variable [3, 15, 16].

The physiological rationale of the proposed multimodal approach is summarized in Figure 1.

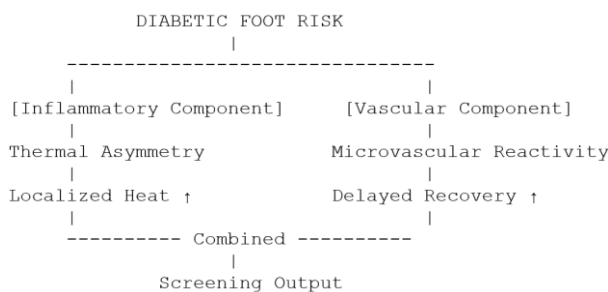


Figure 1. Physiological rationale of the proposed multimodal screening approach.

Figure 1 Physiological rationale of the proposed multimodal screening approach. The system combines plantar thermal asymmetry as a surrogate marker of localized inflammatory stress with post-occlusive microvascular reactivity as an indicator of vascular recovery capacity, providing a dual-domain representation of early neuroischemic diabetic-foot risk.

2.1.1. Thermal Asymmetry

Localized plantar temperature elevation is a recognized marker of inflammatory stress and pre-ulcerative tissue overload. Bilateral comparison improves robustness by reducing environmental bias [8, 17].

2.1.2. Post-occlusive Microvascular Reactivity

Reactive hyperemia reflects vascular recovery capacity following transient ischemia. Alterations in this response have been associated with diabetic vascular dysfunction [16, 37].

2.1.3. Discrete-electronics Approach

Unlike software-based systems, discrete electronics enable direct signal traceability, local calibration, and resilience in constrained environments, which is particularly relevant for Caribbean healthcare settings [20].

2.2. Translational Relevance for Resource-Constrained Environments

The proposed device was intentionally designed for translational applicability in environments with limited technological infrastructure, including community healthcare settings in the Dominican Republic and the Caribbean. In such contexts, device maintainability, hardware transparency, low dependence on software ecosystems, and operational robustness are particularly important. The fully discrete-electronics approach adopted in this work is intended to facilitate local interpretability, simplified maintenance, and reduced infrastructural dependency while preserving clinically relevant physiological screening capability.

3. Materials and Methods

3.1. Study Design and Manuscript Positioning

This work is presented as a biomedical engineering design-and-rationale study, focused on the development of hardware architecture for early screening of neuroischemic diabetic-foot risk.

The manuscript does not report completed clinical validation; instead, it defines:

- 1) the physiological rationale,
- 2) the system architecture,
- 3) the signal-processing framework,
- 4) and a structured pathway for experimental validation.

This positioning is intentional and aims to ensure methodological transparency while establishing a reproducible engineering baseline for future benchtop and clinical evaluation.

3.2. System Overview

The proposed system is a fully analog, discrete-electronics screening platform composed of five functional subsystems:

- 1) Bilateral multisite plantar temperature acquisition
- 2) Reflective optical perfusion sensing
- 3) Controlled brief vascular occlusion and release

4) Analog extraction of post-occlusive hyperemic time-to-peak

5) Comparator-based risk classification and output

The architecture is intentionally designed to operate:

- 1) without microcontrollers,
- 2) without digital signal processing,
- 3) and without software dependence.

All signal acquisition, conditioning, and decision logic are implemented at the hardware level.

The overall architecture of the proposed system is illustrated in [Figure 2](#).

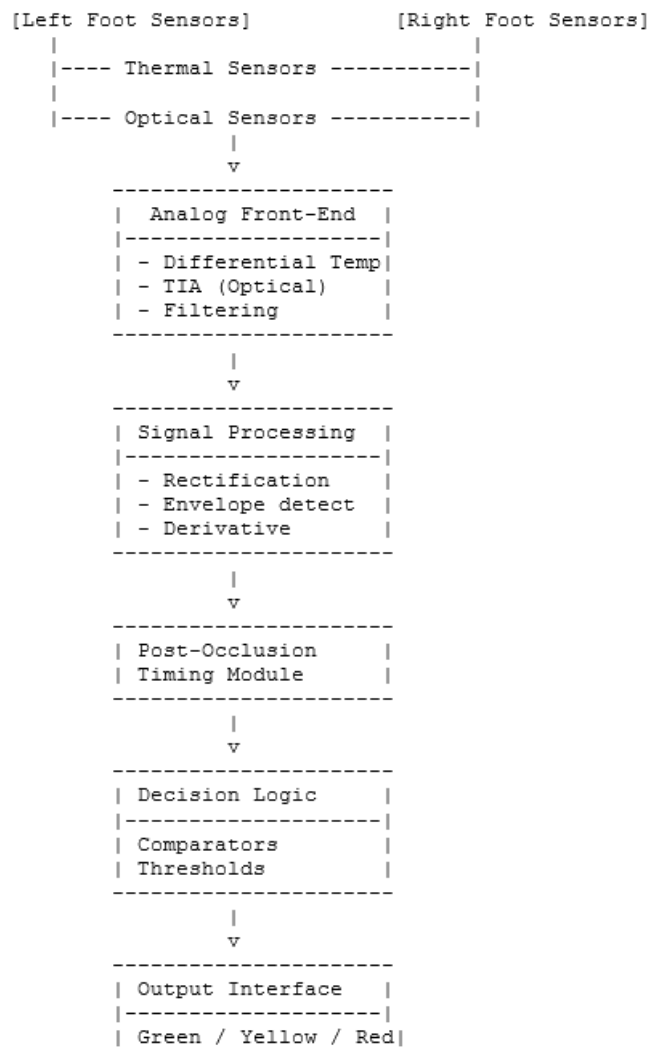


Figure 2. Global architecture of the proposed analog discrete screening system.

Figure 2. Global architecture of the proposed analog discrete screening system. The device integrates bilateral plantar sensing, analog front-end conditioning, signal processing, post-occlusive timing, and hardware-based risk classification. The architecture is entirely implemented without software or microcontrollers, emphasizing local interpretability and robustness in constrained environments.

3.3. Thermal Sensing Subsystem

3.3.1. Sensor Placement

Temperature is measured at anatomically relevant plantar sites associated with high ulceration risk, including:

- 1) hallux,

- 2) first metatarsal head,
- 3) selected midfoot regions.

Sensors are arranged in bilateral homologous pairs to enable direct comparison between right and left foot.

3.3.2. Measurement Model

For each site, the thermal differential signal is defined as:

$$\Delta T_i = T_{R,i} - T_{L,i}$$

and the magnitude:

$$|\Delta T_i|$$

The global thermal indicator is defined as:

$$S_T = \max(|\Delta T_1|, |\Delta T_2|, \dots, |\Delta T_n|)$$

where n is the number of sensor pairs.

3.3.3. Analog Implementation

The thermal subsystem can be implemented using:

- 1) linear analog temperature sensors (e.g., LM35-class),
- 2) differential amplification stages,
- 3) precision rectification circuits,
- 4) comparator-based threshold detection.

The use of bilateral differential measurement reduces:

- 1) environmental temperature bias,
- 2) sensor drift impact,
- 3) and inter-session variability.

3.4. Optical Perfusion Subsystem

3.4.1. Measurement Principle

The measured signal is represented as $P(t)$. The analog signal-processing pathway of the optical subsystem is shown in Figure 3.

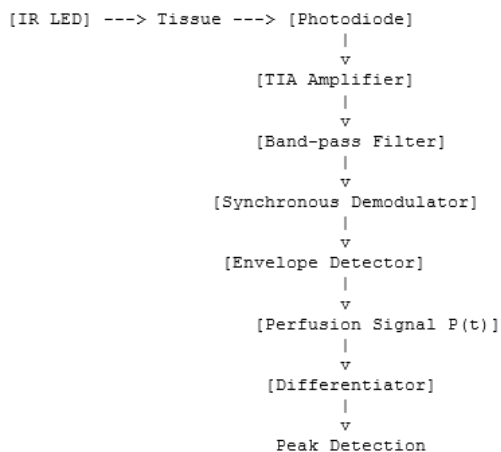


Figure 3. Analog signal-processing chain of the reflective optical subsystem.

Figure 3. Analog signal-processing chain of the reflective optical subsystem. Infrared emission and photodiode detection are followed by transimpedance amplification, filtering, synchronous demodulation, and envelope extraction. The resulting perfusion signal is used for derivative-based detection of post-occlusive hyperemic time-to-peak.

Local perfusion is assessed using reflective photoplethysmography (PPG) with:

- 1) infrared LED emission (~940 nm),
- 2) photodiode detection,
- 3) analog signal conditioning.

The measured signal is represented as: $P(t)$.

3.4.2. Signal Acquisition Chain

The optical signal pathway consists of:

- 1) LED modulation (kHz range)
- 2) Photodiode current detection
- 3) Transimpedance amplification (TIA)
- 4) Band-limited analog filtering
- 5) Synchronous demodulation
- 6) Envelope extraction
- 7) Temporal differentiation

3.4.3. Synchronous Demodulation

Synchronous detection is implemented using analog switching (e.g., CD4053 or CD4066), referenced to the modulation signal.

This approach provides:

- 1) rejection of ambient light,
- 2) improved signal-to-noise ratio,
- 3) increased robustness for non-laboratory environments.

3.4.4. Basal Signal Adequacy

A minimum pulsatile amplitude threshold $A_{PPG,min}$ is enforced using comparator logic to ensure:

- 1) adequate optical coupling,
- 2) valid physiological signal acquisition.

Photoplethysmography has been widely used in clinical and physiological monitoring and is a well-established technique in biomedical instrumentation [2].

3.5. Post-occlusive Vascular Challenge

3.5.1. Procedure

A brief mechanical occlusion is applied using a cuff-based system for a predefined duration.

At release time t_0 :

- 1) perfusion recovery is monitored,
- 2) a timing sequence is initiated.

3.5.2. Physiological Rationale

This active challenge allows assessment of:

- 1) vascular reactivity,

2) microcirculatory reserve,
 3) tissue recovery capacity.
 This distinguishes the system from purely passive monitoring approaches.

3.6. Hyperemic Time-to-peak Extraction

3.6.1. Definition

The primary vascular variable is defined as:

$$T_{peak} = t_{max} - t_0$$

where:

- 1) t_0 = release time,

2) t_{max} = time of maximum perfusion signal.
 The idealized temporal profile of the post-occlusive response is illustrated in Figure 4.

After cuff release at time t_0 , perfusion increases to a peak at t_{max} .

Gráfico (ejes)
 X-axis: Time
 Y-axis: Relative Perfusion Signal
 Curva

Figure 4. Idealized temporal profile of post-occlusive reactive hyperemia. After cuff release at time t_0 , perfusion increases to a peak at t_{max} . The time-to-peak (T_{peak}) is used as a functional marker of microvascular recovery, with delayed responses suggesting impaired vascular reactivity.

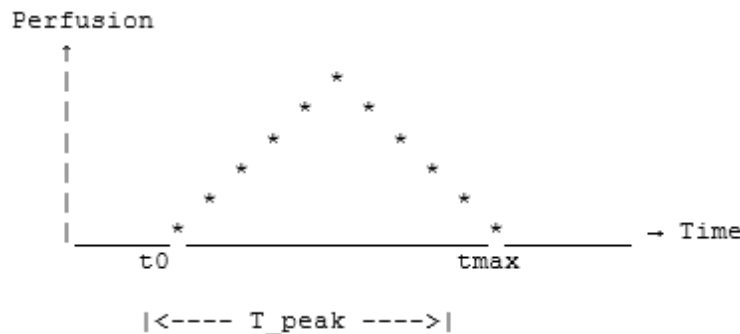


Figure 4. Idealized temporal profile of post-occlusive reactive hyperemia. After cuff release at time t_0 , perfusion increases to a peak at t_{max} .

3.6.2. Detection Method

The maximum is detected using analog derivative criteria:

$$\frac{dP(t)}{dt} = 0$$

after a preceding positive slope.

3.6.3. Hardware Implementation

This can be implemented using:

- 1) analog differentiator circuits,

- 2) zero-crossing comparators,
- 3) gating logic,
- 4) discrete counters (e.g., CD4518, CD4060).

This allows extraction of a time-domain physiological marker without digital processing.

3.7. Risk Classification Framework

3.7.1. Composite Index

A simplified hardware-based risk index is defined as:

$$R = w_1 H(S_T - \theta_T) + w_2 H(T_{peak} - \theta_P) + w_3 H(A_{PPG,min} - A_{PPG})$$

where:

- 1) H is a step function implemented via comparators,
- 2) θ_T is the thermal threshold,
- 3) θ_P is the hyperemic threshold.

The hardware-based classification logic is represented in Figure 5.

Figure 5. Hardware-based decision logic of the proposed screening system. Thermal asymmetry, perfusion signal adequacy, and hyperemic time-to-peak are combined through comparator-based thresholding and discrete logic to produce a local three-level screening output without digital processing.

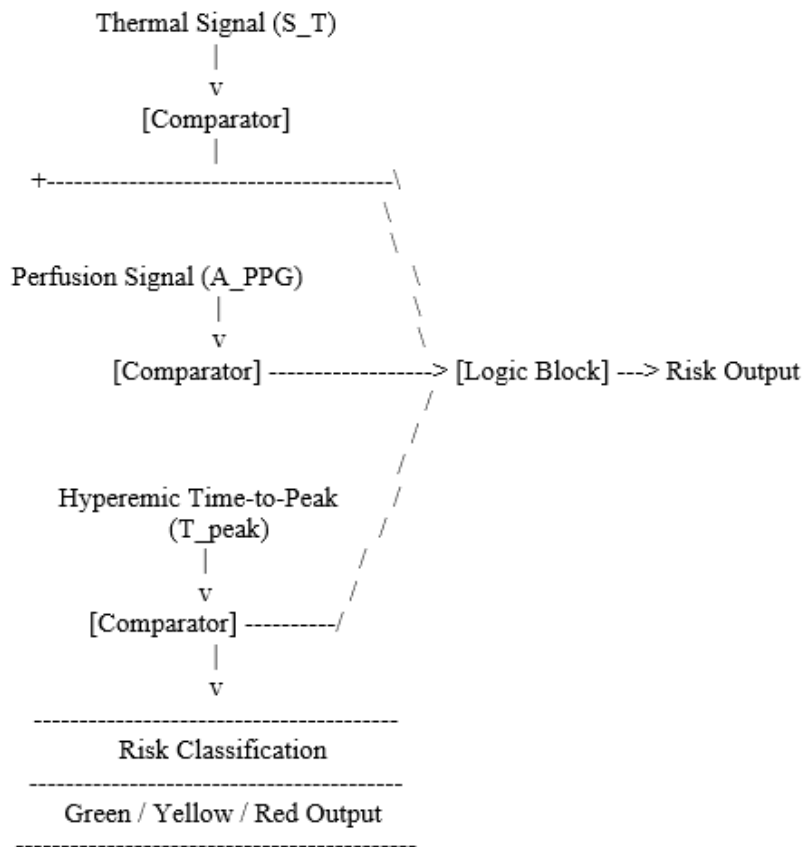


Figure 5. Hardware-based decision logic of the proposed screening system.

3.7.2. Output Representation

The device produces a local screening output:

- 1) Green → low apparent risk
- 2) Yellow → intermediate risk
- 3) Red → elevated neuroischemic risk

This output is generated directly through hardware logic without computational post-processing.

3.8. Hardware Platform

3.8.1. Core Components

The system can be implemented using:

- 1) Operational amplifiers (LM358, TL072, OPA197 class)
- 2) Comparators (LM311, LM339)
- 3) Timing circuits (NE555, CD4060)
- 4) Logic elements (CD4013, CD4518, CD4093)
- 5) Analog switches (CD4053, CD4066)
- 6) Infrared LEDs and photodiodes
- 7) Analog temperature sensors

3.8.2. Power Considerations

The device is intended to operate:

- 1) from battery supply,
- 2) with linear regulation,

- 3) and with separate analog and logic grounding domains.

3.9. Design Constraints

The system was designed under the following constraints:

- 1) no software dependence
- 2) no microcontroller
- 3) no cloud or connectivity requirement
- 4) low component cost
- 5) local manufacturability
- 6) high interpretability
- 7) robustness in variable environments

These constraints are central to the translational relevance of the device.

3.10. Calibration Strategy

Calibration is expected to be performed through:

- 1) baseline thermal equalization,
- 2) adjustable comparator thresholds,
- 3) optical signal amplitude normalization,
- 4) timing calibration using reference oscillators.

This approach prioritizes:

- 1) reproducibility,
- 2) local adjustability,
- 3) and independence from digital calibration routines.

3.11. Design Requirements and Target Performance

The system design is guided by explicit engineering and clinical requirements, summarized in [Table 2](#).

Framing the device around explicit design requirements is

important because the present study is not a completed clinical validation paper, but a concept-and-architecture study. By stating the intended requirements and performance objectives, the manuscript makes the proposed system more reproducible, more auditable, and more suitable for later engineering verification and translational evaluation.

Table 2. Design requirements and expected performance targets for the proposed analog discrete screening device.

Design Domain	Requirement	Engineering Rationale	Expected Target / Working Objective
Clinical purpose	Early screening of neuroischemic diabetic-foot risk	The device is intended for screening and triage, not definitive diagnosis	Three-level local risk output: green / yellow / red
Operating philosophy	Fully analog, software-free, microcontroller-free architecture	To maximize hardware transparency, direct verifiability, and resilience in constrained settings	No firmware, no embedded OS, no cloud dependency
Thermal sensing	Bilateral multisite plantar temperature comparison	Focal asymmetry is more clinically informative than isolated absolute temperature	At least 3 bilateral plantar sites; expandable to 5–6 pairs
Thermal output variable	Maximum bilateral thermal asymmetry	Screening should emphasize focal inflammatory burden	$ST = \max(\Delta T_1 , \Delta T_2 , \dots, \Delta T_n)$
Thermal stability	Repeatable differential acquisition under stable contact conditions	Reduces false interpretation from sensor drift	Stable bilateral differential output during fixed baseline interval
Optical sensing	Reflective infrared perfusion acquisition	Provides a noninvasive surrogate of local vascular behavior	Infrared LED + photodiode reflective channel
Optical robustness	Ambient-light-tolerant acquisition	Field deployment requires resistance to uncontrolled illumination	Synchronous demodulation or equivalent analog rejection strategy
Post-occlusive challenge	Brief, controlled vascular occlusion with reproducible release	Enables functional assessment beyond static perfusion	Short standardized occlusion interval followed by timed release
Vascular output variable	Hyperemic time-to-peak	Simple and physiologically interpretable recovery marker	$T_{peak} = t_{max} - t_0$
Peak detection	Analog identification of post-release perfusion maximum	Must remain consistent with non-digital design philosophy	Derivative-based peak detection with comparator logic
Basal signal adequacy	Minimum acceptable pulsatile optical amplitude	Reduces false classification from poor optical coupling	Comparator-based minimum pulse-quality check
Risk integration	Local hardware combination of thermal and vascular markers	Intended to preserve interpretability and immediate usability	Weighted threshold logic implemented with analog comparators
User interface	Immediate local screening display	Supports point-of-care or outreach use	Green / yellow / red indicator plus optional numeric timing output
Portability	Operation in low-infrastructure environments	Relevant for the Dominican Republic and Caribbean outreach settings	Battery-compatible, self-contained unit
Maintainability	Local serviceability with conventional components	Important for long-term deployment outside high-complexity infrastructures	Use of widely available analog and CMOS components
Calibration	Manual or semi-manual local adjustment	Necessary for discrete-electronics reproducibility	Threshold trimming and baseline calibration at hardware level
Safety positioning	Noninvasive screening device	Avoids overstating maturity or regulatory class	Pre-diagnostic screening and referral support only
Validation	Bench, feasibility, and pilot clinical	Manuscript is design-stage, so validation	Bench characterization → healthy

Design Domain	Requirement	Engineering Rationale	Expected Target / Working Objective
path	stages	must be staged	feasibility → pilot diabetic cohort
Translational goal	Suitability for primary care, community campaigns, and academic prototyping	Aligns the engineering concept with regional health-system realities	Usable in screening, teaching, and prototype-driven translational research

4. Proposed Validation Framework

To avoid overstating maturity, the present manuscript does not report experimental outcomes. Instead, it defines a staged validation pathway consistent with the current design stage.

4.1. Benchtop Electronic Characterization

The first stage should be established:

- 1) bilateral thermal acquisition stability,
- 2) analog optical sensitivity,
- 3) ambient-light tolerance,
- 4) repeatability of peak detection,
- 5) timing accuracy of the post-occlusive measurement chain,
- 6) drift and noise performance under continuous operation.

4.2. Controlled Physiological Feasibility

A second stage should examine signal plausibility in healthy volunteers and lower-risk individuals to verify:

- 1) bilateral thermal symmetry behavior,
- 2) post-occlusive waveform morphology,
- 3) reproducibility of T_{peak} ,
- 4) feasibility of local hardware classification.

4.3. Pilot Clinical Screening Study

A third stage should include diabetic subjects with different risk profiles in order to assess whether the proposed combination of thermal asymmetry and hyperemic timing produces meaningful group-level separation. Candidate groups could include:

- 1) non-diabetic controls,
- 2) diabetic participants without prior foot ulcer,
- 3) diabetic participants with neuropathy, peripheral arterial disease, or prior ulcer history.

4.4. Anticipated Translational Output

If validated, the system could support:

- 1) primary-care screening,
- 2) community diabetic-foot campaigns,
- 3) vascular-risk triage,

- 4) educational hospital use,
- 5) biomedical engineering doctoral work and prototype-driven translational research.

5. Discussion

Previous research has explored thermal sensing [4, 6, 21, 30], optical perfusion [1, 5, 15], wearable systems [6, 28, 29], and vascular assessment techniques [16, 37]. However, these approaches are typically implemented as separate or digitally integrated systems.

The proposed device differs by integrating thermal and vascular domains within a single analog architecture. This is particularly relevant for resource-constrained environments where simplicity and reliability are critical.

The main limitation of this study is the absence of experimental validation, which is planned as future work.

The central contribution of this work is the analog integration of two complementary physiological dimensions of diabetic-foot risk: focal thermal abnormality and post-occlusive vascular reactivity. This is clinically meaningful because neuroischemic diabetic-foot deterioration is not adequately represented by inflammation-only or perfusion-only models. Rather, it emerges from the interaction of mechanical stress, inflammation, neuropathy, macrovascular compromise, and microvascular dysfunction.

From a technological standpoint, the proposal differs from the prevailing direction of diabetic-foot innovation. Current systems frequently rely on smart socks, connected insoles, digital temperature monitoring, and multifactorial remote platforms. These developments are important, but their implementation often depends on software ecosystems, embedded control, data pipelines, and digital maintenance infrastructure. By contrast, the present design adopts a hardware-first biomedical strategy that privileges transparency, verifiability, maintainability, and resilience.

For the Dominican Republic and the Caribbean, that distinction is especially important. In settings where technological continuity, maintenance support, and software-dependent service chains may be inconsistent, a local, self-contained, and explainable screening system may offer practical advantages. Moreover, from an academic perspective, the complete causal chain from physiological hypothesis to hardware implementation remains directly observable, which is highly advanta-

geous for doctoral research, engineering education, and prototype refinement.

From an intellectual-property standpoint, the potentially protectable core does not lie in thermal sensing alone or optical perfusion alone, but in the specific integration of:

- 1) bilateral multisite plantar thermal asymmetry,
 - 2) active post-occlusive vascular challenge,
 - 3) analog time-to-peak extraction, and
 - 4) discrete local risk classification,
- within a fully software-free architecture.

However, several limitations must be acknowledged clearly. First, the present manuscript remains a design-stage study and does not yet include benchtop or human-subject validation. Second, optimal thresholds remain to be experimentally determined and may vary across subpopulations. Third, analog implementations require careful management of component tolerances, thermal drift, and noise accumulation. Fourth, the physiological response to post-occlusive challenge may be influenced by factors beyond diabetic-foot risk alone, including autonomic variability, vascular stiffness, medication, and

measurement-site conditions. These limitations do not invalidate the concept, but they define the next mandatory stage of work.

In order to position the proposed device more clearly within the diabetic-foot technology landscape, representative existing approaches can be compared across physiological target, technological dependency, interpretability, and translational suitability. The purpose of this comparison is not to deny the value of digitally mediated systems, but to clarify the distinct niche occupied by the present hardware-first, software-independent architecture.

Additional studies have examined thermal analysis, guideline-based clinical management, and population-specific diabetic foot characteristics [24, 31, 32, 34-36]. These findings further emphasize the need for screening systems that are both physiologically grounded and adaptable to different healthcare environments. Moreover, recent experimental and applied studies continue to explore temperature-pressure relationships and monitoring strategies in diabetic foot assessment [38].

Table 3. Comparative positioning of the proposed system relative to representative diabetic-foot screening and monitoring technologies.

Technology Category	Main Biomarker(s)	Typical System Architecture	Dependence on Software / Embedded Processing	Active Functional Challenge	Local Interpretability	Suitability for Resource-Constrained Settings	Key Limitation Relative to the Proposed System
Plantar temperature monitoring socks	Local temperature	Wearable digital textile or sock-based platform	High	No	Moderate	Moderate	Typically limited to thermal monitoring alone
Smart insoles / connected plantar platforms	Pressure, temperature, activity	Embedded sensor array with digital acquisition	High	No	Moderate	Moderate to low	Greater technological dependency and higher system complexity
Infrared thermography systems	Surface thermal distribution	Imaging-based digital platform	High	No	Low to moderate without trained interpretation	Low to moderate	High equipment cost and reduced portability
Optical perfusion assessment systems	Perfusion, blood-flow-related optical signals	Optical instrumentation, usually digitally processed	Moderate to high	Sometimes	Moderate	Low to moderate	Often not optimized for simple local screening workflows
Multifactorial digital diabetic-foot systems	Temperature, pressure, adherence, activity, remote monitoring	Connected digital ecosystem	High	Usually no	Variable	Low in infra-structurally constrained settings	Strong ecosystem dependence and maintenance burden
Post-occlusive vascular laboratory methods	Reactive hyperemia, vascular recovery	Specialized vascular testing environment	Moderate to high	Yes	Moderate	Low	Limited portability and low field suitability

Technology Category	Main Biomarker(s)	Typical System Architecture	Dependence on Software / Embedded Processing	Active Functional Challenge	Local Interpretability	Suitability for Resource-Constrained Settings	Key Limitation Relative to the Proposed System
Proposed analog discrete multimodal system	Plantar thermal asymmetry + post-occlusive hyperemic time-to-peak + basal pulse adequacy	Fully analog, discrete-electronics local screening platform	None	Yes	High	High	Requires staged validation and threshold calibration

As shown in Table 3, the proposed system is not intended to outperform advanced digital platforms in data richness or long-term connectivity. Its distinguishing contribution lies instead in combining multimodal physiological screening with low infrastructural dependence, local interpretability, and a fully discrete implementation. This makes it particularly relevant for translational contexts in which robustness, serviceability, and direct clinical usability may be prioritized over ecosystem complexity.

6. Conclusion

This work proposes a novel analog discrete screening system integrating thermal asymmetry and vascular reactivity. The approach is clinically relevant, technologically distinct, and suitable for low-infrastructure environments. It provides a foundation for prototype development and future validation.

Its significance lies in three converging domains:

- 1) clinical relevance, because diabetic-foot burden remains substantial in the Caribbean and the Dominican Republic;
- 2) engineering originality, because it combines complementary biomarkers in a transparent hardware architecture;
- 3) translational potential, because it can support prototype development, doctoral research, and academic patent exploration.

The proposed system therefore constitutes a credible basis for future benchtop characterization, pilot clinical validation, and intellectual-property development.

Abbreviations

PPG	Photoplethysmography
T _{peak}	Time to Peak Hyperemia
S _T	Thermal Asymmetry Indicator
PAD	Peripheral Arterial Disease

Author Contributions

Baldo Alberto Luigi Dalporto: Conceptualization, Methodology, Supervision, Writing – original draft

Sabine Mary: Data curation, Methodology, Writing – review & editing

Santiago Gallur: Supervision, Validation, Writing – review & editing

Data Availability Statement

No experimental dataset was generated in the present design-stage manuscript.

Conflicts of Interest

The authors declares no conflicts of interest.

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