SERBIAN JOURNAL OF ELECTRICAL ENGINEERING
Vol. 22, No. 2, June 2025, 165-181

UDC: 004.94:681.84.087 DOI: https://doi.org/10.2298/SJEE2502165S

Original scientific paper

Advanced Stimulation and Dog Behavior Analysis System

Milan Stojanović[1], Dejan Stevanović[1], Slavimir Stošović[2]

Abstract: This paper describes a system for analyzing the behavior of a hunting dog using the detection of the dog's barking and its speed of movement, as well as a system for sound and vibration stimulation of the dog and LED module. These systems are part of a more complex system for tracking hunting dogs that enables hunters to monitor the movement and behavior of their dog during the hunt. Monitoring a dog's barking provides critical insight during a hunt, especially when the dog is out of sight and pursuing game. By tracking the number of barks per minute, the hunter can determine whether the dog is actively in pursuit. If the hunter needs the dog to return or to stop chasing prey, they can issue an audible or vibratory command, provided the dog has been adequately trained. Detecting the dog's movement speed is equally important in bird hunting, since a dog freezes in place when it locates a bird. The GPS module can pinpoint the dog's location but cannot reveal its behavior at that spot.

Keywords: Bark detection, Movement detection, Sound stimulus, Vibration stimulus.

1 Introduction

Electronic dog tracking systems play a crucial role in hunting, enabling hunters to monitor their dog's location and movement in real time for a more seamless and controlled hunting experience. Leading manufacturers in this field include Garmin [1], DogTrace [2], and Dogtra [3]. However, a common drawback of these systems is their external antenna, which can obstruct movement or even pose a risk of injury when navigating dense vegetation. A strong competitor to these established brands is the Canandi system [4],

[1]University of Niš, Faculty of Electronic Engineering; Niš, Serbia;
milancestojanovic@elfak.rs, https://orcid.org/0009-0008-5598-041X;
dejan.stevanovic@elfak.ni.ac.rs, https://orcid.org/0000-0002-4444-5496
[2]College of Applied Technical Studies; Niš, Serbia;
slavimir.stosovic@akademijanis.edu.rs, 0009-0008-6550-6156

Colour versions of the one or more of the figures in this paper are available online at https://sjee.ftn.kg.ac.rs developed in Serbia, which addresses these challenges with innovative design solutions.

The Canandi system is composed of three main elements: a dog collar, a hunter unit, and a mobile application. The collar is equipped with GPS technology, allowing it to determine the dog's precise location. It then transmits this information via radio link to the hunter unit, which subsequently forwards the data to the hunter's mobile phone using Bluetooth. This setup enables real-time tracking of the dog's movements without requiring an internet connection or mobile network coverage. With a single hunter unit, up to 20 dogs can be tracked within a 20-kilometer range, provided there is an unobstructed line of sight. The Canandi system stands out from its competitors by introducing several significant innovations.

First key innovations that sets this system apart from competitors is the integration of both the radio communication antenna and the GPS antenna within the collar housing. This design eliminates the need for an external antenna, which in some competing systems can extend up to 50 cm in length. By embedding the antennas, the collar allows the dog to move freely through dense vegetation and bushes without the risk of entanglement or injury, ensuring both functionality and safety in challenging environments.

The second key innovation is an advanced anti-theft system. Each collar has a unique security code required for registration in the mobile application, ensuring only the rightful owner can use it. The collar powers on with a button press but can only be turned off through the registered app. If stolen and removed from the dog's neck, it remains operational until the battery depletes, giving the hunter time to locate it or recover the stolen dog.

The third key innovation is the implementation of smart hunting groups, allowing hunters to connect and share information using their hunter units and mobile devices. In this way they can communicate effectively even in areas without internet or mobile network coverage. Each hunter in the group can designate key locations, such as checkpoints, feeders, and water sources, as well as mark areas where wildlife activity has been observed and define important hunting zones.

Effective dog stimulation during a hunt is essential for enabling the hunter to issue commands remotely [5, 6]. This can be achieved through vibration, sound, or electrical stimulation [7 – 9] The Canandi system has been enhanced to incorporate vibration and sound-based stimulation, ensuring responsive dog training without physical proximity [10]. Since the use of electrical stimulation on animals is prohibited in the EU, this method is not included in the system. When the dog perceives a vibration or sound signal, it instinctively halts movement or disengages from chasing prey, allowing the hunter to maintain control.

Chapter 2 provides an in-depth overview of the Canandi hunter unit system, followed by Chapter 3, which focuses on the Canandi dog collar system. Chapter 4 examines the bark detection system, while Chapter 5 discusses the mechanism for tracking dog movement speed. Chapter 6 explores the system for sound and vibration stimulation. Chapter 7 presents details on the LED module. Chapter 8 presents the practical implementation of the system, and Chapter 9 presents the conclusion of the paper.

2 Canandi Hunter Unit System

The main part of the Canandi hunter unit system is the ESP32 microcontroller that communicates with the mobile phone and LoRa module.

LoRa module (*Long Range Modulation*) is used for communication between the hunting unit and the dog collar. LoRa is a radio communication technology developed to create low-power, wide-area networks required for IoT (*Internet Of Things*) applications. LoRa uses radio frequency bands that do not require a special license. In Europe, that frequency band is 863 – 870/873 MHz. The main characteristic of this radio technology is very low energy consumption and the range up to 20 km.

ESP32 system on a chip microcontrollers come with integrated Wi-Fi and dual-mode Bluetooth. These microcontrollers are widely used in IoT applications. ESP WROOM 32 is used for Canandi hunter unit system. It uses its built-in BLE (*Bluetooth Low Energy*) module to send information about the dog and the hunt to the mobile phone, as well as to receive commands given in the mobile application and send them to the collar. Fig. 1 shows a block-level schematic of the Canandi hunter unit system.

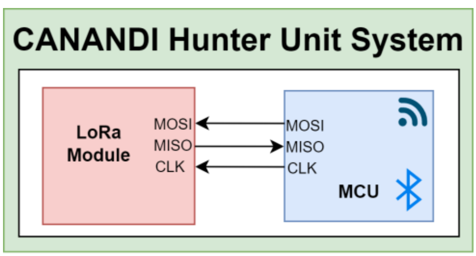

Fig. 1 – *Block-level schematic of the Canandi hunter unit system.*

3 Canandi Dog Collar System

The central part of the Canandi dog collar system is the microcontroller ATmega328P that controls all the modules connected to it.

The collar is equipped with a GPS module that accurately determines the dog's position. This module communicates with satellites via a radio link, processing the received data to calculate precise location coordinates, including altitude, latitude, and longitude. Since the global GPS satellite network provides comprehensive coverage, the collar's GPS receiver ensures continuous position tracking regardless of location. The positional data is continuously gathered, processed by the microcontroller, and transmitted to hunter unit using LoRa, and after that to mobile phone using BLE, enabling the hunter to monitor the dog's movements in real time. Fig. 2 shows a block-level schematic of the Canandi dog collar system.

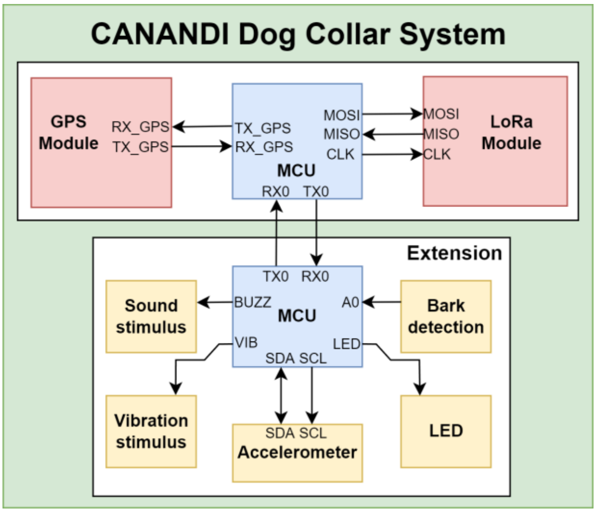

Fig. 2 – *Block-level schematic of the Canandi dog collar system.*

4 Bark Detection System

The bark detection system operates by identifying the sound emitted by the dog while barking. For sound detection, a microphone is required that is small enough to be compactly integrated into the system while ensuring good sensitivity. The selected microphone is CMEJ-0415-42-LP [11]. It has a sensitivity of –42 dB (±3 dB) at 94 dB SPL, providing reliable sound detection for accurate bark recognition.

The microphone generates an analog signal at its output when it detects sound vibrations on its diaphragm. Since this signal is relatively weak, an amplifier circuit is required to boost it to a level suitable for processing by the microcontroller. The MAX9814 amplifier [12] is used for this purpose. It features a low-noise amplifier, a variable gain amplifier, and a voltage generator for microphone polarization. Fig. 3 shows the internal block-level structure of the MAX9814 amplifier.

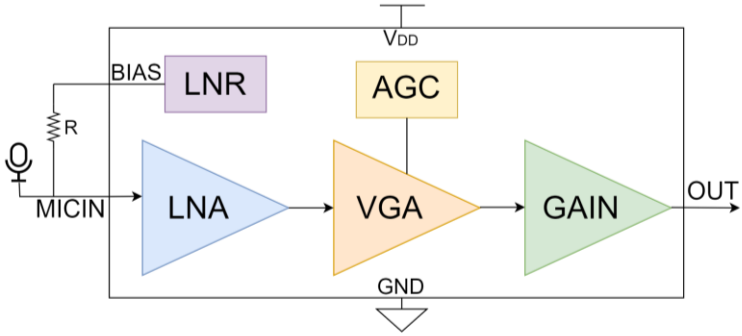

Fig. 3 – *Block-level structure of the MAX9814 integrated circuit.*

Due to its automatic gain control and low-noise polarization, it is ideal for amplifying the weak signal produced by the microphone. The low-noise reference (LNR) block provides a 2V bias to the microphone, preventing the MICIN input signal from clipping to ground. The low-noise preamplifier (LNA) has a fixed gain of 12dB, while the automatic gain control (AGC) dynamically adjusts the signal strength. The variable gain amplifier (VGA) modifies the gain between 20dB and 0dB depending on the AGC threshold. The GAIN block offers selectable amplification levels of 8dB, 18dB, and 28dB, ensuring flexible signal enhancement. Finally, the OUT pin delivers the amplified output from the integrated circuit. A schematic of the sound detection system is presented in Fig. 4.

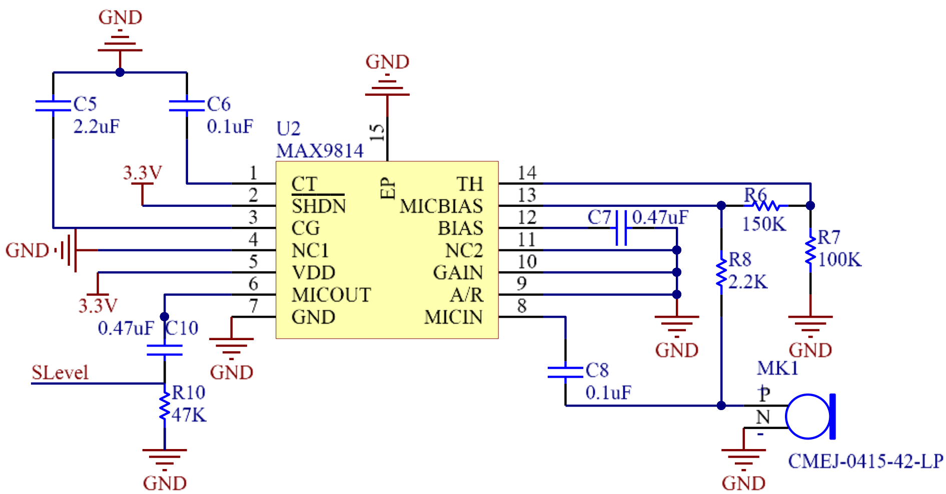

Fig. 4 – *Schematic of the sound detection system.*

The amplified continuous signal from the output of the amplifier is directed to the microcontroller's analog input, where it goes through analog-to-digital conversion. Sound is sampled 512 times per second, with this process occurring once every 5 seconds. Each collected sample is added to the variable *sound_vol_sum*. After gathering all samples, their average value is calculated and then converted into a *sound* level in decibels (dB) using (1):

$$sound = 20\log_{10}(sound\_vol\_sum / 512)\,. \tag{1}$$

The central part of the Canandi dog collar system is the microcontroller ATmega328P that controls all the modules connected to it.

The digital information about the detected sound level is further analyzed to determine whether it corresponds to a bark or an ambient noise. The system filters out sound values that fall below a user-defined threshold, ensuring that only dog barks are recognized while weaker environmental noises are ignored. Since the intensity of a dog's bark varies, users can customize the threshold to match their dog's vocal strength. Through testing, the optimal sound level threshold *snd_th* in dB can be identified. This threshold data is transmitted from the main dog-tracking system to the behavior analysis system

When the detected sound level in decibels (dB) exceeds the predefined threshold, it is identified as a bark, whereas values below the threshold are ignored. Each time a bark is registered, the *bark_counter* increments. To keep the user informed, the counter value is periodically sent to the main dog-tracking system every 10 seconds, allowing real-time monitoring of the dog's barking frequency. Fig. 5 illustrates the algorithm used to determine whether a detected sound qualifies as a bark, following the described process.

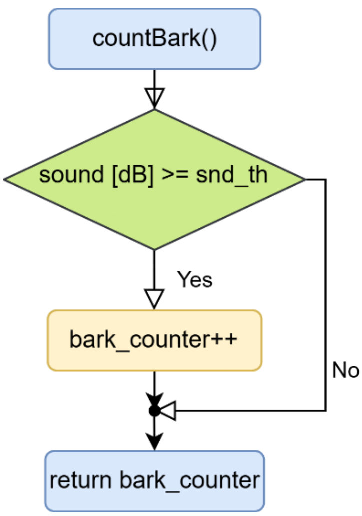

Fig. 5 – *Algorithm for detecting whether a sound corresponds to barking.*

5 Motion speed Detection System

For hunters who rely on bird-tracking dogs, monitoring the dog's movement speed is crucial. During a hunt, the dog moves swiftly, following the scent of a bird. As soon as it spots the bird, it suddenly stops, fixes its gaze, and remains completely still, carefully tracking every movement. In that moment, it is essential for the hunter to be aware of the situation and react accordingly.

A microelectromechanical sensor, ICM20602 [13], has been utilized for detecting movement speed. The ICM20602 sensor measures a dog's movement speed using a 6-axis motion tracking system, combining a 3-axis gyroscope for spatial orientation and a 3-axis accelerometer for acceleration detection. It features a 16-bit analog-to-digital converter (ADC), programmable filters, a temperature sensor, and a 1 KB FIFO buffer for efficient data transfer. Due to its precision, it is widely used in robotics, drones, and mobile devices. The sensor's built-in ADC converts continuous acceleration data into a digital format, which is then transmitted to the MCU via I2C for further processing.

The gyroscope features a measurement range of ±250, ±500, ±1000, ±2000 degrees per second, providing low-noise output data at frequencies of up to 8 kHz. As for the accelerometer, its measurement range spans ±2g, ±4g, ±8g, ±16g, where g represents acceleration due to gravity (9.81 m/s²). It is capable of generating output data at frequencies of up to 4 kHz. Both the gyroscope and accelerometer allow for adjustable measurement ranges, which can be configured via commands sent from the microcontroller to the ICM20602 module. The microcontroller and the ICM20602 sensor communicate through I2C communication lines. The schematic of the ICM20602 integrated circuit is shown in Fig. 6.

The ICM20602 integrated circuit provides the microcontroller with raw, unprocessed digital acceleration data for each of the three axes. To obtain accurate values, this data must be divided by a specific factor, which depends on the selected measurement scale range. The following section presents the corresponding factor values for each measurement scale:

– For ±2g, the factor is 16384.0;

– For ±4g, the factor is 8192.0;

– For ±8g, the factor is 4096.0;

– For ±16g, the factor is 2048.0.

Dividing the raw acceleration value by the appropriate factor converts it to a value in g. To verify accuracy, the accelerometer is tested by observing the *z*-axis when the ICM20602 chip is positioned horizontally. If the result is close to 1.0g (9.81 m/s², Earth's gravitational acceleration), the settings are correct. The same factor is then applied to acceleration values for the *x* and *y* axes.

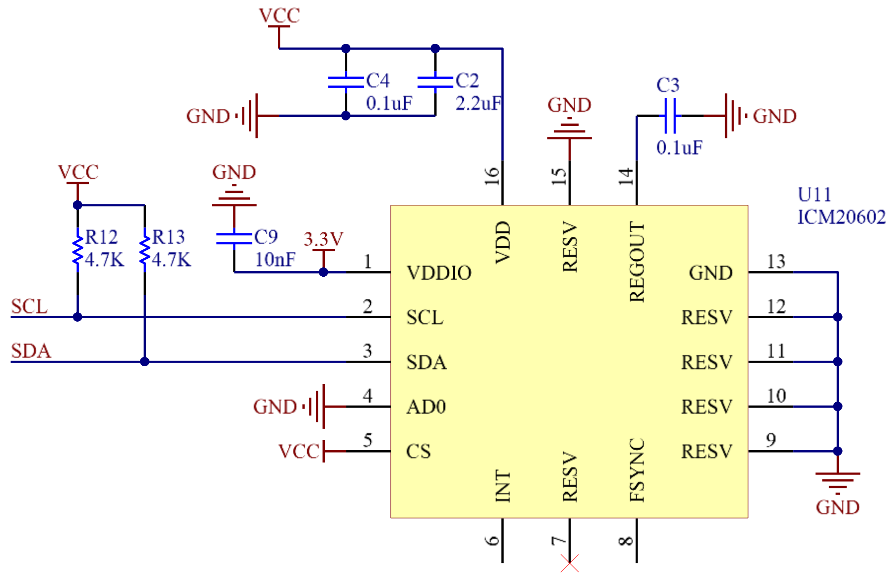

Fig. 6 – *Wiring diagram for the integrated circuit ICM20602.*

Depending on its speed, the dog can be in one of three states: resting, sneaking, or running. These states are determined based on two acceleration thresholds: a lower and an upper limit. These thresholds, measured in m/s², are transmitted via UART communication, allowing the hunter to configure them through the main dog tracking system.

When the accelerometer detects acceleration below the lower threshold, the dog is classified as resting. If the acceleration falls between the two thresholds, the dog is sneaking, cautiously advancing toward its target. If the acceleration exceeds the upper threshold, the dog is running, actively pursuing its prey.

Since this system is integrated into a collar worn around the dog's neck with the sensor positioned underneath, the focus should be on acceleration changes along the x and y axes, as acceleration on the z-axis may approximate Earth's gravitational acceleration. After collecting acceleration data for the x and y axes, their average value is calculated.

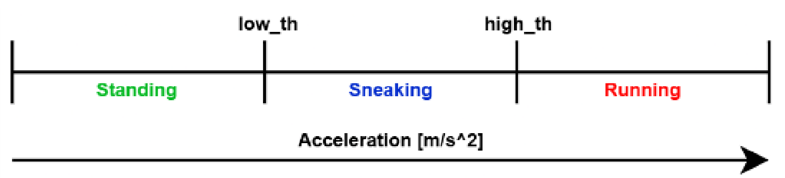

Fig. 7 – *The condition of the dog depending on the acceleration and limit values.*

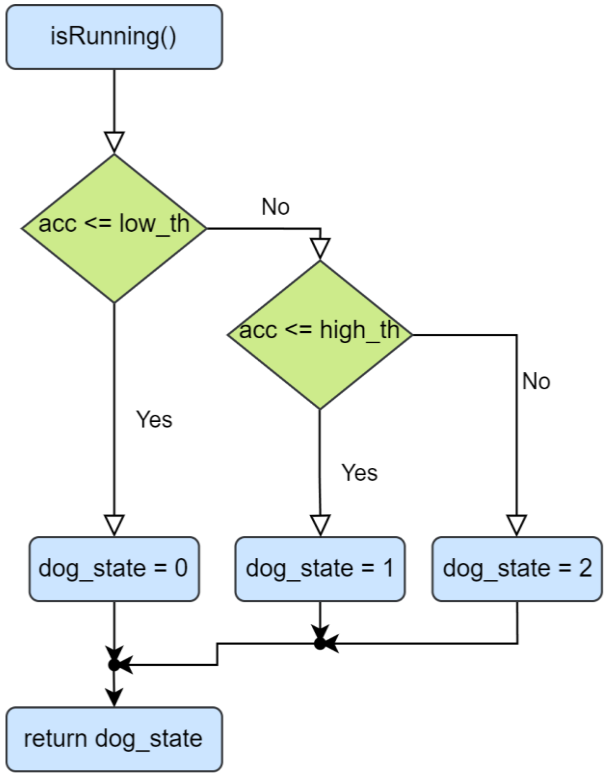

Fig. 8 – *Algorithm for determining the state of the dog based on acceleration and limit values.*

Fig. 7 provides a graphical representation of the dog's states as a function of acceleration and threshold values, while Fig. 8 presents the algorithm responsible for this part of the system. The parameters *low_th* and *high_th* correspond to the lower and upper acceleration thresholds, respectively, and the *acc* is the average value for acceleration on x and y axes.

6 System for Sound and Vibration Stimulation

Effective stimulation is critical during hunting to ensure a dog halts its pursuit of prey on command. The system enables hunters to deliver targeted stimuli remotely via a mobile app. Commands are transmitted wirelessly – first via Bluetooth to a handheld hunting unit, then through a radio link to the dog's collar. Hunters can customize both the type of stimulus (sound or vibration) and duration (adjustable in seconds) based on the situation. When triggered, the collar activates the selected stimulus, providing immediate control over the dog's behavior during a chase.

6.1 Sound stimulation system

Sound stimulation is performed using a small buzzer placed on a printed circuit board inside the device housing. There are two types of buzzers [14]:

1. Active buzzers generate sound with DC power via a built-in oscillator and piezoelectric disk. Their disadvantage is that the sound frequency remains constant at around 2kHz ± 300Hz, limiting tonal control.
2. Passive buzzers need an external AC signal (e.g., PWM from a microcontroller or 555 timer) to produce sound, as they don't have an internal oscillator. When current flows through their internal coil, it generates a magnetic field that vibrates a metal disk, creating sound. Adjusting the PWM signal's frequency changes the buzzer's pitch.

Buzzers can also be categorized based on their internal structure [15]:

1. Piezoelectric buzzers use pressure-sensitive material to generate voltage, vibrating a diaphragm at its resonant frequency for sound. Powered by DC, they emit a loud, sharp high-pitched tone, outperforming other buzzers in volume.
2. Electromagnetic buzzers use a coil and magnet: current through the coil creates a magnetic field, moving the magnet and vibrating its attached diaphragm to generate sound.
3. Mechanical buzzers feature a flexible membrane that begins to oscillate when exposed to mechanical force or pressure. The resulting vibrations lead to sound production.
4. Electromechanical buzzers incorporate a small motor that rotates a disk to generate vibrations.
5. Magnetic buzzers use a ferromagnetic core, like iron or steel, to generate vibrations and sound. The core is linked to a pole piece, acting as a magnet's North Pole. When current flows through the coil, it creates a magnetic field that makes the core vibrate, producing sound.

Given that the system is battery-powered, a buzzer with low power consumption and sufficient sound output is required, and due to its small dimensions, it can be easily integrated into compact designs.

For this purpose, the magnetic buzzer CBT-09427-SMT [16] was selected. Its operating voltage range includes 3.3V, which matches the system's requirements. Since this is a passive buzzer, it requires a PWM signal as an excitation source to generate sound.

A magnetic buzzer consists of a coil and a small magnet, effectively forming an RL circuit. Due to its inductive nature, precautions must be taken to manage the energy released when the voltage across the buzzer's terminals suddenly drops. Additionally, external interference can cause the buzzer to resonate, leading to an induced current in the coil, which is undesirable.

To mitigate these issues, a diode is placed in parallel with the buzzer to dissipate the excess energy and absorb the induced current. In this setup, a Schottky diode (D1) is used, rated for a reverse voltage of 10 V, with a reverse leakage current of under 5 µA at 3.3 V. The wiring diagram for the buzzer is shown in Fig. 9. If a piezoelectric buzzer were used instead, a high-value resistor (≥ 1kΩ) would be sufficient to dissipate the excess energy instead of a diode.

To produce sound, the buzzer needs to be driven by a PWM signal *BUZZ* with a 50% duty cycle and the desired frequency. Fig. 10 illustrates how the buzzer's sound characteristics vary depending on the frequency of the driving signal.

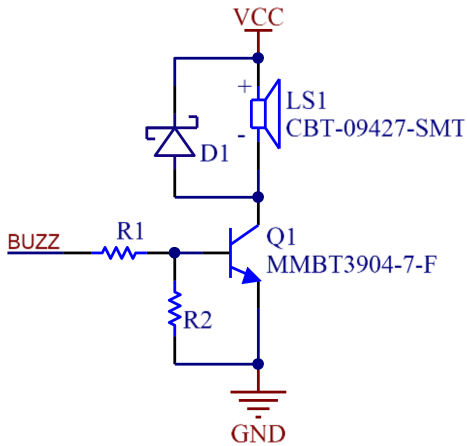

Fig. 9 – *Schematic of the sound stimulation system.*

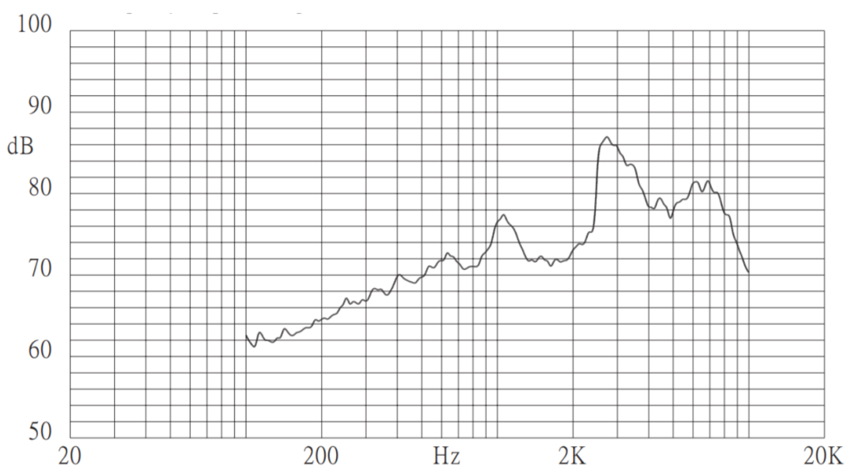

Fig. 10 – *Dependence of sound intensity on the excitation signal frequency.*

Based on its characteristics, the buzzer reaches its maximum sound level of 87 dB at a driving signal frequency of 2730 Hz. Therefore, the microcontroller should generate the *BUZZ* signal at this frequency. For comparison, a dog's bark has an intensity slightly above 70 dB, human speech can reach up to 60 dB, and traffic noise is around 80 dB. The buzzer's 87 dB sound level is strong enough for a dog to hear loud and clear, even while barking actively and frequently. At this frequency, the buzzer can draw up to 110 mA of current. To drive it, an NPN transistor MMBT3904-7-F [17] is used in a common-emitter configuration, labeled as Q1 in the schematic. Since this transistor can handle up to 200 mA, it ensures that the buzzer operates at full power with its required 110 mA.

The digital pins of the microcontroller can provide up to 20mA of current. When using a PWM signal with a 50% duty cycle, this value increases to 40mA. To protect the microcontroller, a base resistor R_1 is added to limit the current flowing into transistor Q1. Since the maximum collector current I_C during operation is 110 mA, and the transistor's minimum gain h_{FE} is 30, the required base current I_B can be calculated using (2), determining the appropriate limit for the current through R_1:

$$I_B = I_{C\_\max} / h_{FE\_\min} \ . \tag{2}$$

The maximum current through resistor R_1 is determined to be I_B = 3.667 mA. Given that the driving voltage is V_{CC} = 3.3 V and the transistor's saturation voltage is V_{BEsat} = 0.65 V, the minimum required resistance for R_1 can be calculated using (3):

$$R_1 = (V_{CC} - V_{BE\_sat}) / I_B \ . \tag{3}$$

This equation gives approximated value of resistance R_1 under assumption that $R_2 >> R_1$. The equation results in a calculated value of 722.66 Ohms for R_1. However, a standard 1 kΩ resistor will be used instead. To keep the transistor off when there is no PWM signal, resistor R_2 needs to be added. Its value is typically set to ten times that of resistor R_1, resulting in a resistance of 10 kΩ.

6.2 Vibration stimulation system

Vibration stimulation works on a similar principle: the hunter issues a command via their phone, specifying the duration of the vibration, and this information is transmitted from the phone to the hunting unit, then to the collar, and finally delivered to the stimulation system. The role of vibration stimulation can be the same as sound stimulation, but it depends on how the dog is trained to respond. Vibration stimulation is particularly useful in situations where a command needs to be given without using a loud sound.

For the implementation of vibration stimulation, a small button-type vibration motor is required, capable of operating at a 3.3 V supply voltage. Since the system is battery-powered, the motor must have low power consumption while providing sufficient intensity and vibration speed. The selected motor is the 316040001 Vibration Motor [18], which achieves a maximum speed of 10,000 RPM and has a maximum current draw of 80 mA.

A PWM signal is not required to drive this motor; instead, applying voltage to its pins is sufficient. This is achieved by setting the VIB_ON_OFF pin of the microcontroller to a logic high, which controls the motor operation for a specified duration in seconds or milliseconds. However, the vibration motor is not directly connected to the microcontroller. Instead, it is interfaced through the NPN transistor MMBT3904 [17] controlled by the microcontroller via resistor R_3, as shown in Fig 11.

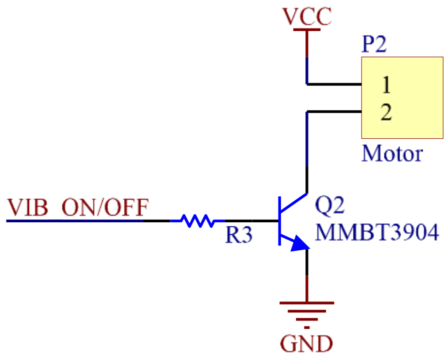

Fig. 11 – *Schematic of the vibration stimulation system.*

Fig. 12 – *Motor for vibration stimulation.*

A 220-ohm resistor (R_3) is connected between its input and the transistor's drive pin to ensure proper functionality. The vibration motor used is shown in Fig. 12. With a diameter of 10 mm, it can be compactly placed within the device housing. During assembly, the motor should be firmly and securely attached to the housing to ensure efficient transmission of vibrations throughout the entire casing, making them detectable to the dog.

7 LED module

The system also includes an LED module, primarily designed to aid in visually locating the dog in dark environments or low-light conditions.

The system is configured so that the LED can be controlled via a mobile application. When the user sends a command to toggle the LED, the signal is relayed through the hunting unit to the dog's collar and then to the LED module. Upon receiving the command, the microcontroller adjusts the *LED_ON/OFF* pin to a HIGH or LOW state, turning the LED on or off accordingly. Fig. 13 shows the circuit schematic for driving the LED diode D2 using the microcontroller.

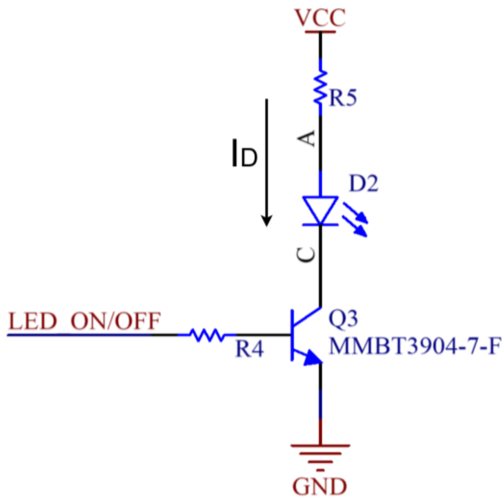

Fig. 13 – *LED module schematic.*

For this application, an LED with high-intensity illumination that can be integrated into the system's PCB is required. The SPMWHT541ML5XAVMS6 LED [19] was selected due to its luminous flux of 36-38 lm, ensuring consistent brightness for precise lighting applications. With a color temperature of 6500K, the LED emits cool white light, closely resembling daylight to provide a sharp and well-defined visual output. Regarding power consumption, the LED operates at a maximum current of 65mA and can withstand up to 200mA under forward bias. The MMBT3904-7-F [17] transistor, which is also used in the buzzer circuit, regulates the current and controls the LED.

The value of resistor R_4 is calculated using (4), while the value of resistor R_5 is derived from (5):

$$R_4 = (V_{CC} - V_{BE}) / (I_D / h_{FE\_\min}), \tag{4}$$

$$R_5 = (V_{CC} - V_D - V_{CE\_sat}) / I_D, \tag{5}$$

where V_{CC} = 3.3 V, V_{BE} = 0.3 V, diode current I_D = 65 mA, h_{FE_min} = 30, diode forward voltage drop V_D = 2.8 V, V_{CE_sat} = 0.3 V. Calculated values for resistors are: R_4 = 1 kΩ and R_5 = 3 Ω.

8 Practical Implementation of the System

The practical implementation of the described system was finalized with the design of the system's printed circuit board. Fig. 14 shows the footprint of the printed circuit board, while Fig. 15 presents the assembled board with all components.

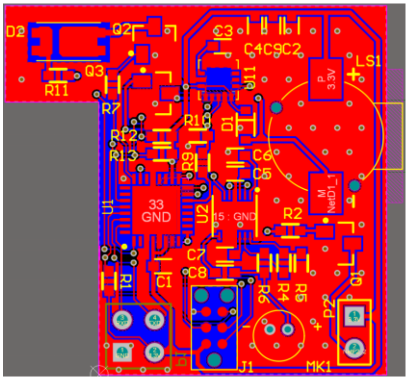

Fig. 14 – *Printed circuit board footprint.*

Fig. 15 – *Assembled printed circuit board.*

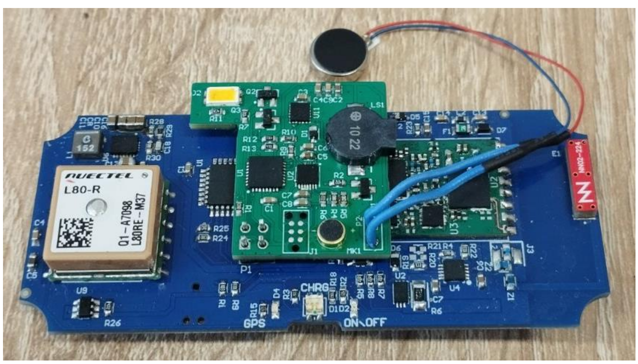

Fig. 16 – *Printed circuit board of the Canandi collar system with the upgraded circuit board of designed system.*

The designed advanced system for stimulation and dog behavior analysis system has been integrated into the Canandi collar tracking system. Fig. 16 presents the printed circuit board of the Canandi collar system along with the upgraded circuit board for mentioned system.

9 Conclusion

This paper describes enhancements to the Canandi dog tracking system through the addition of four modules: a stimulation module, a bark detection module, a dog speed tracking module, and an LED module.

The stimulation module enables hunters to deliver commands as stimulation using sound or vibrations to their dogs during hunts, ensuring precise control even at long distances. The LED module complements this by providing visual signals via a durable collar light, improving visibility in dense foliage or low-light conditions. By observing the dog's movement speed, the hunter can determine whether the animal is stationary, stealthily approaching its target, or actively pursuing prey. Alongside this, the frequency of the dog's barking provides crucial information, helping the hunter make informed decisions about their next steps and reactions.

Field tests of the collar mounted system during actual hunts provided several insights. Combining auditory signals with controlled vibrational cues significantly improved both the speed and precision of command responses in high activity hunting breeds. Behavioral analyses showed that dachshunds tolerate vibrations better while hounds respond more readily to auditory commands, underscoring the need to tailor stimulation protocols to each breed and individual. Our results indicate that the ideal training regimen uses concise, precisely timed vibrational cues alongside auditory prompts, enhancing the dog's responsiveness while preserving its well-being. Finally, integrating accelerometer-based tracking with bark detection provides objective data on posture, movement and situational responses, enabling handlers to interpret and predict a dog's behavior in the field.

10 Acknowledgments

This work has been supported by the Ministry of Education, Science and Technological Development of Republic of Serbia.

11 References

[1] Garmin: Dog Tracking and Training. Available at: https://www.garmin.com/en-US/c/outdoor-recreation/sporting-dog-tracking-training-devices/.

[2] DogTrace: Dog Training and Tracking systems. Available at: https://www.dogtrace.com/en/m-11-gps-tracking-training-system.

[3] Dogtra: Pathfinder Hunter Dog Tracking System, Available at:

https://dogtra.com/collections/gps-dog-collar.

[4] Canandi: Hunter Dog Tracking System, Available at: https://canandi.com/stranica-proizvoda/.

[5] C. Byrne, L. Freil, T. Starner, M. M. Jackson: A Method to Evaluate Haptic Interfaces for Working Dogs, International Journal of Human-Computer Studies, Vol. 98, February 2017, pp. 196-207.

[6] K. Pryor: Don't Shoot the Dog!: The New Art of Teaching and Training, Bantam Books, New York, Toronto, London, 1999.

[7] S. McLeod: Pavlov's Dogs Experiment and Pavlovian Conditioning Response, Available at: https://www.simplypsychology.org/pavlov.html.

[8] L. China, D. S. Mills, J. J. Cooper: Efficacy of Dog Training with and without Remote Electronic Collars vs. A Focus on Positive Reinforcement, Frontiers in Veterinary Science, Vol. 7, July 2020, p. 508.

[9] A. C. Johnson, C. D. L. Wynne: Comparison of the Efficacy and Welfare of Different Training Methods in Stopping Chasing Behavior in Dogs, Animals, Vol. 14, No. 18, September 2024, p. 2632.

[10] M. Stojanovic, D. Stevanovic, S. Stosovic: System for Analyzing the Behavior and Stimulation of Hunting Dogs, 11th International Conference on Electrical, Electronic and Computing Engineering (IcETRAN), Nis, Serbia, July 2024, pp. 1–4.

[11] Electret Condenser Microphone, Model: CMEJ-0415-42-LP, Same Sky, Available at: https://www.sameskydevices.com/product/resource/cmej-0415-42-lp.pdf.

[12] Microphone Amplifier with AGC and Low-Noise Microphone Bias, Model: MAX9814, Analog Devices, Available at:

https://www.analog.com/media/en/technical-documentation/data-sheets/MAX9814.pdf.

[13] High Performance 6-Axis MEMS MotionTracking Device, Model: ICM-20602, InvenSense, Available at:

https://invensense.tdk.com/wp-content/uploads/2016/10/DS-000176-ICM-20602-v1.0.pdf?ref_disty=digikey.

[14] G. Lambert: Active Buzzers vs Passive Buzzers, Circuit Basics, Available at: https://www.circuitbasics.com/what-is-a-buzzer/.

[15] N. Agnihotri: What are the Different Types of Buzzers?, Engineers Garage, Available at: https://www.engineersgarage.com/buzzers-types-transducer-indicator-piezo-magnetic/.

[16] Magnetic Buzzer Transducer, Model: CBT-09427-SMT-TR, Same Sky, Available at: https://www.sameskydevices.com/product/resource/cbt-09427-smt-tr.pdf.

[17] 40V NPN Small-Signal Transistor in SOT23, Model: MMBT3904-7-F, DIODES Incorporated, Available at: https://www.diodes.com/assets/Datasheets/MMBT3904.pdf.

[18] Vibration ERM Motor 3V, No. 316040001, Seeed Technology Co., Ltd, Available at: https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/2234/1020-15-003-001_Spec.pdf.

[19] Middle Power LED Series 5630, Model: LM561C CRI80, Data Sheet, Samsung, Available at: https://download.led.samsung.com/led/file/resource/2022/05/Data_Sheet_LM561C_CRI80_Rev.9.2.pdf.