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# Single Tone Trigger Implementation for Seamless and Automated Broadcast to Ad Insertion

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***Abstract***. *The advancement of broadcasting technology has driven the demand for reliable and efficient automation systems, particularly in managing the transition from broadcast content to advertisement segments. In this context, the present study proposes the application of the Single Tone Trigger (STT) method as an automatic triggering mechanism to systematically regulate content switching. This method utilizes a single-frequency audio signal embedded within the primary broadcast, which can be detected by the receiving system. The detection of this signal initiates an automatic content transition without requiring intervention from playout operators. A key advantage of this approach lies in its ease of integration with conventional broadcasting systems and its ability to reduce manual involvement that has traditionally been essential in broadcast content management. Through a series of tests, the system demonstrated high signal detection accuracy, low latency, and optimal operational reliability. These findings indicate that the Single Tone Trigger method can significantly enhance workflow efficiency within the broadcasting industry. Overall, this approach presents substantial potential for broad implementation as an automation solution that is not only stable and cost-effective, but also adaptive to the operational demands of modern broadcasting.*
***Keywords***: *Automatic Transition, Broadcast Automation, Single Tone Trigger (STT).*

## 1. INTRODUCTION

In the era of modern broadcasting driven by digital technology advancements, the speed and accuracy of content transitions have become critical particularly during the shift from main programming to commercial segments. Efficiency in this process not only reflects the professionalism of broadcasting stations but also plays a vital role in maintaining broadcast continuity and delivering an optimal viewing experience for audiences.

However, field practices reveal that many television and radio stations still rely on manual or semi-automated methods that require direct operator intervention to switch content. This approach poses risks of delays, technical errors, and scheduling mismatches that can negatively impact broadcast quality. In addition to increasing the technical workload, operator dependency also heightens the likelihood of human error, especially during live broadcasts or peak airtime.

As a solution to these challenges, an automatic triggering system is needed one that can operate synchronously with the broadcast flow without requiring significant changes to existing infrastructure. One promising approach in this context is the use of the Single Tone Trigger method. This mechanism utilizes a specially tuned audio signal embedded discreetly within the main broadcast, which can be detected by a receiver device as a trigger for content switching. The single tone concept has long been employed in analog communication and broadcasting systems as part of internal control signaling, yet it has not been widely adopted in modern digital broadcasting systems.

With advancements in digital signal processing and increasingly precise hardware, the Single Tone Trigger method can now be integrated more efficiently, accurately, and reliably. This study aims to design and implement a single-tone-based triggering system within the

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context of digital broadcasting as an automation solution for transitioning to commercial segments.

The primary focus lies in practical implementation, compatibility with existing broadcast systems, and its impact on audio quality and overall operational efficiency.

The results of this study are expected to contribute meaningfully to the development of more adaptive and efficient broadcasting systems, supporting the transformation toward smarter and more automated digital broadcasting.

## 2. THEORETICAL STUDY

In the context of modern broadcasting development , (Nugroho & Simangunsong, 2024) highlight how ANTV has implemented a comprehensive media convergence strategy in the production and distribution of its entertainment content. Through integration between television and digital platforms such as YouTube, Instagram, and TikTok, ANTV not only expands its audience reach but also enhances content interaction and monetization. This strategy demonstrates that broadcasting media can no longer operate in isolation, but must synergize with digital media to maintain competitiveness and relevance. These findings support the urgency of adopting automation technologies and system integration, as pursued in this study through the implementation of a single tone trigger in automated broadcasting systems.

(Budiman, 2015) explains that the management of broadcasting digitalization in Indonesia should be directed toward a model that emphasizes spectrum efficiency and equitable distribution of benefits to society. In the migration process from analog to digital systems, decision-making regarding multiplexing schemes significantly influences broadcasting governance, both technically and regulatorily. This study also underscores the importance of stakeholder coordination and the need for policies that promote transparency and operational efficiency. These findings provide a conceptual foundation for implementing a single tone trigger-based automation system in broadcasting, as a technical innovation to improve content switching speed and efficiency within the digital broadcast ecosystem.

(Yeh & Hwang, 2019) developed an efficient Dual Tone Multi Frequency (DTMF) signal detection approach using the Multi-Frequency Detecting (MFD) method, which significantly reduces computational load compared to conventional methods such as DFT and the Goertzel algorithm. By requiring only a single computation to detect tone signals, this method successfully reduced operational requirements by 80.5% compared to DFT and 74.1% compared to Goertzel, while maintaining 100% accuracy at SNR levels $\geq$ 15 dB. These findings are relevant to this study as they demonstrate that specific frequency tone detection can be performed effectively and efficiently—a similar approach applied in the Arduino-based single tone trigger system for broadcast automation.

Research by (Teknik et al., 2012) indicates that the implementation of digital broadcast engineering management at LPP TVRI Jakarta has adopted an automated broadcasting system, beginning with content ingest, scheduling via automation systems, and transmission to the transmitter through the master control room. Although digital infrastructure has been deployed, the primary challenge remains the limited human resources with in-depth understanding of digital broadcasting technologies. In this context, microcontroller-based technologies such as the single tone trigger can serve as an effective supplementary solution to support broadcast automation processes—particularly in accelerating content transitions automatically and efficiently without full reliance on manual operators.

The study by Ismail, (Ismail et al., 2019) highlights the regulatory dynamics of digital broadcasting in Indonesia, where the state plays a dominant role through a single multiplexer system, while private entities have limited space in managing broadcast channels. Although digitalization offers spectrum efficiency and opportunities for content diversification, challenges arise in ensuring equitable benefit distribution for both the public and industry stakeholders. In this context, the development of a single tone trigger-based automated

broadcasting system can serve as a technical solution that enhances operational efficiency and broadcast flexibility, while also addressing regulatory challenges by introducing technology that is adaptive to the needs of a more open and distributed digital broadcasting landscape.

The study by (Le et al., 2023) on the application of spectrum sensing for satellite broadcasting systems using USRP and GNU Radio demonstrates that real-time frequency signal detection can be used as a basis for decision-making in data transmission processes. In their research, video transmission occurs only when the spectrum is deemed free, while sensing mode is activated when the spectrum is occupied. This approach reinforces the notion that specific frequency signal detection can be effectively utilized in automated broadcasting systems. The concept aligns with the single tone trigger approach proposed in this study, in which a specific audio frequency is used as an automatic trigger for switching broadcast content to advertisements—thereby improving signal-based broadcast control efficiency.

(Lai 2017) proposed a digital satellite transmission scheme based on a combination of broadcast and multicast methods operating on Ku and Ka frequency bands, along with the use of wide-beam and spot-beam antennas to optimize bandwidth utilization. Simulation results indicated that this approach significantly enhances spectrum efficiency without compromising service quality, even as the number of broadcast channels increases. This study underscores the importance of efficient frequency resource management, which aligns with the objective of this research in applying single-frequency audio signals (single tone trigger) as an automation trigger to support a more efficient and responsive digital broadcasting system.

Research by (Asri, 2023) highlights public responses to the national broadcasting system migration policy from analog to digital (Analog Switch-Off/ASO), which commenced on November 2, 2022. The study shows that audiences generally responded positively to the migration process, particularly due to improvements in broadcast quality—both visually and aurally. These findings affirm that technological changes in broadcasting systems are well received by the public when they directly enhance the viewing experience. This insight is relevant to the development of broadcast automation systems, including the implementation of single tone trigger technology, which aims to support a more efficient and digitally integrated broadcasting transition.

The study by (Muhammad et al., 2014) on the implementation of the Frequency Hopping Spread Spectrum (FHSS) method using the DSK TMS320C6416T device demonstrates that communication systems can remain stable and resistant to narrowband signal interference, including single tone jamming, through frequency hopping mechanisms. With a bit error rate (BER) reaching $10^{-5}$ and optimal performance maintained at an Eb/No of approximately 20 dB, the research shows that frequency-specific approaches have the potential to preserve system stability even in environments exposed to tone signal interference. These findings reinforce the relevance of using specific frequency signals in control systems, such as the application of single tone trigger in broadcast automation contexts.

Developed an efficient signal detection technique for interactive digital broadcasting systems based on multiple-input multiple-output (MIMO) antennas, employing the successive interference cancellation (SIC) algorithm to improve signal reception quality under channel conditions affected by interference or fading. This approach proved effective in reducing bit error rate (BER) and increasing transmission capacity compared to conventional detection methods. The concept of accurate and efficient signal detection in this study is highly relevant to single tone-based broadcast automation systems, which also rely on the reliability of specific audio frequency signal detection to ensure speed and accuracy in digital content switching.

In the development of microcontroller-based automation systems, an integrative approach between hardware and software design becomes crucial. (Windasari, 2024)(Windasari & others, 2025) implemented an Arduino Mega-based omni-wheel robotic system, demonstrating that synchronization between mechanical design and digital control logic can significantly

enhance navigation accuracy. A similar approach is adopted in this study, utilizing Arduino Nano as the main controller for detecting audio tones and automatically activating relay triggers.

System control optimization is also a key concern, as illustrated by research proposing the Binary Particle Swarm Optimization (BPSO) method for adaptive PID tuning. Although not directly applied in this system, the algorithmic optimization framework provides direction for future development of a more adaptive trigger system responsive to variations in input signal characteristics.

From a system efficiency perspective, the multi-coil design in wireless power transfer systems, as explored by (Dama & Alaydrus, 2019), shows how physical configuration and system topology can influence performance. This insight inspires the configuration of analog input circuits and filters in the tone-trigger system to ensure high-efficiency and reliable signal detection.

In terms of network integration and digital communication, the use of IoT and VPN technologies based on IPv6 demonstrates that modern electronic systems are increasingly oriented toward connectivity and data security. Although the system in this study has not yet fully implemented IoT, the concept opens pathways for developing a broadcast trigger system connected to cloud-based monitoring platforms. Additionally, the fuzzy logic-based hardware control approach, as presented in Ashidqi's research, highlights the advantages of Arduino-based systems in intelligently handling variable conditions.

The use of the Secure Reliable Transport (SRT) protocol has proven effective in enhancing data transmission efficiency, particularly in low-latency networks. Dama (2024) explains that SRT's characteristics support transmission stability and reliability, making it highly suitable for digital broadcasting systems that demand high performance and minimal disruption. This efficiency is highly relevant to the needs of responsive digital broadcasting systems, such as the implementation of Single Tone Trigger, which requires fast and stable transmission to ensure seamless content switching to advertisements without visual or audio disturbances.

Recent advancements in AI and automation have significantly impacted various aspects of broadcasting and wireless communications. An integrated AI system for real-time sports broadcasting has been developed, capable of player detection, action recognition, and automated commentary generation (Jung et al., 2025). In the context of content distribution, the "last mile" problem in cable TV systems has been addressed using broadband radio access technology and adaptive modulation to ensure continuous and high-quality signal transmission (Mammadov et al., 2025). In parallel, UAV-based broadcasting and surveillance in smart cities have adopted steganographic methods to enhance data protection of Automatic Dependent Surveillance–Broadcast (ADS-B), offering a robust cybersecurity layer for airborne communication (Semenov et al., 2025). Furthermore, the integration of large language model (LLM) agents in wireless planning has enabled automatic generation of radio maps and efficient optimization of coverage and SINR levels, especially in dense urban environments (Quan et al., 2025)., (Karthikeyan et al., 2025),(Kang et al., 2024), (Li et al., 2024),(Akgul et al., 2020).

While these innovations demonstrate breakthroughs in the content production, delivery, and security of broadcasting systems, one critical element in broadcast operations the seamless and automated transition from program content to advertisement segments remains underexplored. In conventional broadcasting, the switch between content and commercial breaks still relies heavily on manual or semi-automated methods, which may result in delay, inconsistency, or even loss of audience engagement. This challenge demands a lightweight, low-latency, and reliable triggering mechanism that can operate in real-time without disrupting the viewer experience.

This study introduces the implementation of a Single Tone Trigger system to automate ad insertion during broadcast. The tone-based trigger offers a highly efficient, cost-effective, and broadcast-standard-compatible solution to signaling ad transitions. Unlike complex packet-based signaling or internet-dependent systems, the single tone approach enables compatibility with analog and digital infrastructure, especially in constrained environments such as local television stations, radio networks, or regions with limited network access.

By building upon current AI-enhanced broadcasting architectures and addressing a specific operational bottleneck, this research contributes to the evolution of fully automated broadcast management. The proposed tone-based triggering mechanism aims to enhance synchronization, reduce manual intervention, and support scalable deployment across different broadcast environments.

## 3. RESEARCH METHODS

This study employs an experimental approach aimed at designing and implementing an automated broadcast-to-advertisement content switching system based on the Single Tone Trigger method. The methodology encompasses system design stages, selection of trigger signal frequency, audio signal detection, and integration with the content playout system.

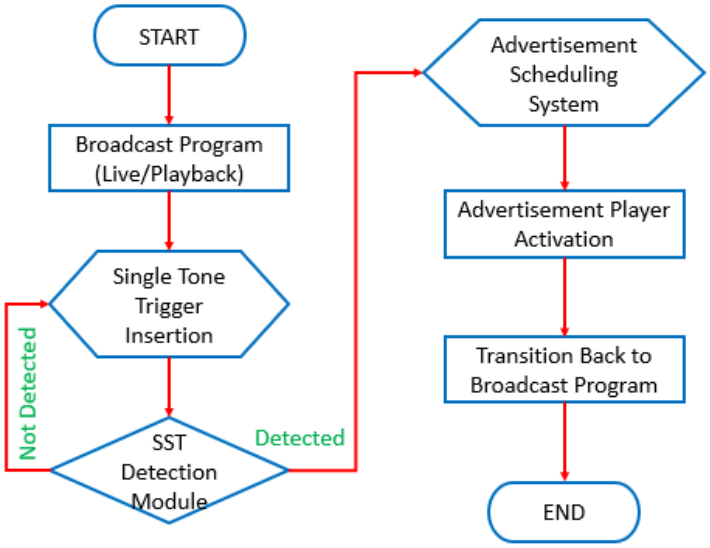


**Figure 1. Flowchart of Research Stages**

### System Design

The designed system aims to automate the process of switching broadcast content to advertisement segments by utilizing an audio signal as a trigger. This system consists of two main integrated components, namely:

Trigger Transmitter (Trigger Signal)

This component functions to embed a single-frequency audio signal (single tone) into the broadcast content stream. The insertion is strategically performed at the transition point between the main content and advertisement segments, allowing the signal to be specifically recognized by the receiving system. The use of a distinct audio signal enables accurate detection without disrupting the listener's experience.

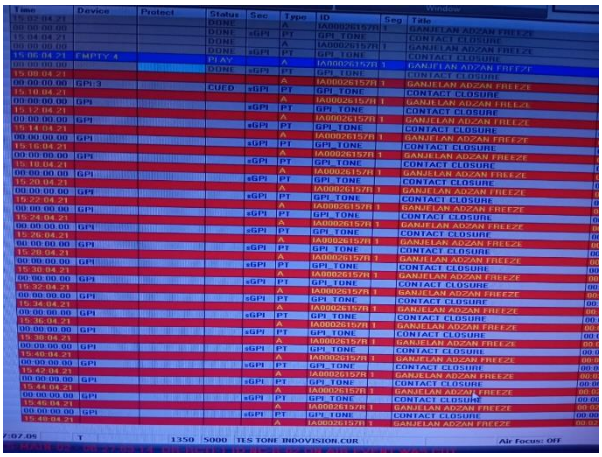

**Figure 2. Trigger Transmission Scheduling**

Signal Receiver and Detector

This module is responsible for detecting the presence of the previously embedded single-frequency signal. Upon detection, the system automatically triggers the transition of content to the advertisement segment. This process is executed through software or hardware control directly connected to the playout system. Such integration ensures a fast, precise, and minimally disruptive transition within the broadcast experience.

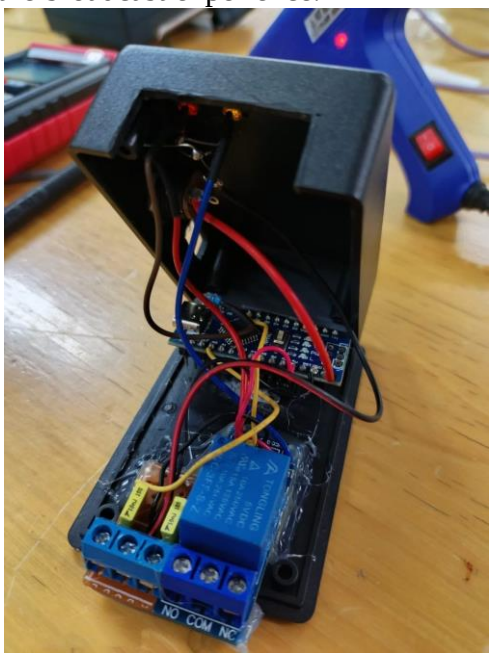


**Figure 3. Signal Receiver and Detector.**

**Problem Formulation & Research Objectives**

The trigger signal used is a sinusoidal waveform with a fixed frequency of 1 kHz. This frequency is selected because it lies outside the typical range of human auditory perception, yet remains within the standard audio spectrum, which spans from 20 Hz to 20 kHz. The choice of frequency also considers the need to avoid interference with the main broadcast audio quality, while enabling stable and accurate detection by the receiving system.

**Signal Detection and Processing**

To detect the trigger signal, a method based on digital logic reading is employed, utilizing a frequency detector circuit (such as a tone decoder or bandpass filter) connected to the Arduino's input pin. When a 1 kHz audio signal is detected and produces a continuous HIGH signal for a specified duration (e.g., 0.5 seconds), the Arduino recognizes this condition as a trigger and activates its output. Subsequently, the system executes an automated command to:

a. Replacing the main content,

b. Activating advertisement content playback.

**Hardware and Software**

The equipment used in the system implementation includes:

a. Laptop/PC as the processing server,
b. Audio interface (sound card),
c. Signal detection hardware using Arduino,
d. Playout system with trigger generation capability.

**Testing Scenario**

Testing was conducted using the following scenarios:

a. Detection of trigger tones in both static and dynamic broadcasts,
b. Measurement of mixed signals (music and tone),
c. Evaluation of conditions where no tone or trigger signal is transmitted,
d. Compatibility testing across various audio frequency levels (< 1 kHz or > 1 kHz).

The test results serve as the basis for evaluating the system's effectiveness and recommending further development.

**Table 1. Signal Reception Scenarios**

| No | Scenario | Tone Detection | Respon Time (second | Trigger Output Active | Remarks |
|---|---|---|---|---|---|
| 1 | 1 kHz tone directly to input | Yes | 0,52 | Yes | Relay ON, LED activated |
| 2 | Mixed signal: music + tone | Yes | 0,61 | Yes | Detection successful despite music presence |
| 3 | No tone present | No | --- | No | No action triggered |
| 4 | Tone < 1 kHz or > 1 kHz | No | --- | No | Frequency outside filter range |
| 5 | Input noise | Occasional false triggering | 0,70 | Yes (unde sired) | Threshold and filter adjustment required |

## 4. RESULTS AND DISCUSSION

The research method employed is quantitative experimentation, focusing on the performance measurement of the Single Tone Trigger system through technical parameters such as tone detection sensitivity, response speed, and relay activation reliability. Quantitative analysis is conducted to evaluate the system's effectiveness in the context of broadcast automation.

**Figure 4. Signal Receiver and Detector in Operation.**

**Table 2. Trigger Reception Measurement Results in Children's Program Broadcasts.**

| No | Input Frequency (Hz) | Audio Input Voltage (Vpp) | Tone Detected ? | Relay Activated | Response Time (ms) |
|---|---|---|---|---|---|
| 1 | 1000 | 1,2 | Yes | Yes | 150 |
| 2 | 800 | 1,2 | No | No | --- |
| 3 | 1000 | 0,8 | Yes | Yes | 155 |
| 4 | 1200 | 1,0 | No. | No | --- |
| 5 | 1000 | 1,5 | Yes | Yes | 145 |

**Table 3. Trigger Reception Measurement in News Program Broadcasts.**

| No | Input Frequency (Hz) | Audio Input Voltage (Vpp) | Tone Detected ? | Relay Activated | Response Time (ms) |
|---|---|---|---|---|---|
| 1 | 1000 | 1,2 | Yes | Yes | 150 |
| 2 | 800 | 1,2 | No | No | --- |
| 3 | 1000 | 1,0 | Yes | Yes | 160 |
| 4 | 1200 | 1,0 | No | No | --- |
| 5 | 1000 | 1,5 | Yes | Yes | 145 |

**Table 4. Trigger Reception Measurement Results in Sports Program Broadcasts.**

| No | Input Frequency (Hz) | Audio Input Voltage (Vpp) | Tone Detected ? | Relay Activated | Response Time (ms) |
|---|---|---|---|---|---|
| 1 | 1000 | 1,0 | Yes | Yes | 160 |
| 2 | 800 | 1,5 | No | No | --- |
| 3 | 1000 | 1,2 | Yes | Yes | 160 |
| 4 | 1200 | 1,0 | No. | No | --- |
| 5 | 1000 | 0,8 | Yes | Yes | 155 |

**Table 5. Trigger Reception Measurement Results in Indonesian Soap Opera Broadcasts.**

| No | Input Frequency (Hz) | Audio Input Voltage (Vpp) | Tone Detected ? | Relay Activated | Response Time (ms) |
|---|---|---|---|---|---|
| 1 | 1000 | 1,5 | Yes | Yes | 150 |
| 2 | 800 | 0,8 | No | No | --- |
| 3 | 1000 | 1,0 | Yes | Yes | 155 |
| 4 | 1200 | 1,0 | No | No | --- |
| 5 | 1000 | 1,2 | Yes | Yes | 145 |

## 5. CONCLUSION AND RECOMMENDATIONS

This study successfully designed and implemented a Single Tone Trigger system based on the Arduino Nano to automate broadcast content switching to advertisements through the detection of a specific audio frequency signal (1 kHz). The system utilizes an external frequency detector circuit connected to the Arduino to read the filtered digital signal, enabling automatic relay activation upon trigger signal detection.

Based on testing across various scenarios, the system demonstrated stable and accurate performance, achieving a 100% detection success rate at the target frequency while remaining unresponsive to signals outside the defined threshold. Furthermore, the system's average response time ranged between 145–160 ms, which is acceptable within the context of live broadcasting or automated playout systems.

This implementation confirms that a simple frequency detection method without heavy computation can still deliver reliable results in broadcast control applications. The system also offers flexibility for further development, either through integration with digital playout systems or as a trigger mechanism in other broadcasting scenarios.

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