



Implementation of Dynamic Gain Control on Signal Analyzer Devices

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ABSTRACT

Dynamic Gain Control (DGC) is a control technique that allows automatic adjustment of system gain based on input signals. This research examines the implementation of DGC on signal analyzer devices to improve measurement accuracy and performance. In this research, we implemented and evaluated the effectiveness of DGC in a signal analyzer device using a microcontroller and function generator as input signal sources. The research results show that DGC can improve system performance in overcoming varying signals and interference

INTRODUCTION

Signal analyzers are important devices in signal measurement and analysis, used in various applications such as telecommunications, electronics, and device testing. Dynamic Gain Control (DGC) allows the signal analyzer device to automatically adjust the gain according to the input signal, increasing measurement accuracy and adaptability to changing signals. Input signals or signals detected by a sensor will have a variety of amplitudes in several units used such as Volt peak to peak (V_{pp}), Volt root mean square (V_{rms}), Volt dc, Volt ac or forms of analysis such as Volt mean, Volt peak. The diversity of the voltage range (Dynamic Range) that is detected will greatly interfere with the voltage analysis process. For example, human muscle signals will have very dynamic voltage range conditions for different subjects, another example is that a voltmeter used by a field inspection agency will easily be damaged if it is not equipped with Auto Range to suppress the dynamic range of the measured voltage.

In an Electrical Engineering learning institution, the Dynamic Gain Control method is really needed to be taught to students so that they are able to improvise measurement processes that require Dynamic Gain Control. Basically, Dynamic Gain Control is Automatic Gain Control but with a few additional methods. The method in question is the process of recording the highest peak voltage data and doing a percentage of the input, then providing feedback and signal reduction for the amplifier circuit used. The goal of DGC is to avoid distortion of signals that are quite strong (large amplitude). The expected result is that the signal can be detected in its entirety at the maximum height display. System Design : The system designed consists of Signal Analyzer Device DGC-optimized device to improve measurement accuracy. Function Generator Generates input signals with various shapes and frequencies.

Microcontroller For signal processing and dynamic gain adjustment. Implementation of Function Generator Settings Generates sinusoidal, triangular and square signals with various frequencies and amplitudes. Microcontroller Programming Implementing the DGC algorithm on the microcontroller (ATX mega 128) to adjust the gain automatically. Calibration and Testing Calibrate the signal analyzer device and carry out tests with input signals from the function generator. Measurement Accuracy Assesses the extent to which the signal measurement with DGC is close to the actual value. Response Time The time required for the system to adjust gain to signal changes. System Stability The ability of a system to remain stable and accurate under various signal conditions. In this dynamic gain control on signal generators, there are several formulas that are important for understanding how to set the gain. Here are some general formulas that are often used.

LITERATURE REVIEW

Automatic Gain Control

AGC (Automatic Gain Control) is an electronic system that automatically adjusts the gain of a signal to maintain a consistent output amplitude, even when the input signal amplitude varies. AGC is commonly used in communication

systems, radio receivers, and audio equipment to ensure signal quality and prevent distortion or signal loss.

$$G_{output}[n] = G_{static} + \mu (G_{target} - G_{measured}[n])$$

$G_{output}[n]$ is the gain produced at sample time n . $G_{measured}[n]$ is the gain measured at n time samples, and can be calculated based on the processed input signal. G_{static} is the static gain or default value set. G_{target} is the desired target gain. μ is the control factor or step size that determines the response speed. In the system above, the process of using an ADC (Analog-to-Digital Converter) is usually used to convert analog signals to digital, the results of digital processing on the microcontroller are used to measure the gain, then a DAC (Digital-to-Analog Converter) is used to produce the signal. output with appropriate gain.

Signal Generator: The main component that produces the output signal. This signal can be a sinusoidal wave, square wave, or other waveform according to the application. *Analog Input (Voltage):* The analog input signal (for example voltage) whose gain will be controlled before being fed to the ADC. *ADC (Analog-to-Digital Converter):* Converts an analog signal (input) into a digital format that can be processed by a microcontroller. *Microcontroller:* The core processing unit that controls the overall operation. It receives data from the ADC, performs calculations to determine the required gain, and controls the DAC. *DAC (Digital-to-Analog Converter):* Converts the digital signal produced by the microcontroller into an analog signal corresponding to the set gain level. *Gain Control Logic:* The part of the microcontroller or separate block that determines the gain value based on the current input conditions and applies control rules accordingly.

Output Signal: The output signal produced after the gain control process. This signal has been converted according to the gain rules programmed in the microcontroller.

Handling Time Constants

The time parameter is very important in gain control. The time constant in gain control on a microcontroller can be implemented by adding or subtracting the gain value within a set time. For example, to apply constant time τ , the calculation can be done by:

$$G_{output}[n] = G_{output}[n-1] + \tau \Delta t \cdot (G_{target} - G_{output}[n-1])$$

where:

Δt is the time interval between the samples taken.

This implementation allows the microcontroller to dynamically control the signal generator gain, ensuring that the output signal remains appropriate to the needs of a particular application, such as in precision measurements, audio systems, or communications applications. This method exploits the advantages of microcontroller digital processing to provide stable and accurate control of signal dynamics.

Computing on Microcontrollers

The use of microcontrollers involves the use of fast and efficient digital calculations. For example, for AGC implementations, PID (Proportional-Integral-Derivative) or FIR (Finite Impulse Response) filter control algorithms can be used to calculate gain changes based on the input and target signals.

Fuzzy Logic Implementation

The application of fuzzy logic for dynamic gain control using a microcontroller involves several main steps in design and implementation. Fuzzy logic is a mathematical approach that can be used to handle uncertainty and complexity in gain regulation, especially in situations where imprecise or ambiguous rules must be made. Following are the general steps in using fuzzy logic for dynamic gain control.

1. Fuzzification

The first process in fuzzy logic is to convert input in the form of numerical values (for example, input signal levels) into linguistic variables or fuzzy sets. For example, linguistic variables for input signal levels could be "low", "medium", and "high", with membership functions determining how strongly each input value satisfies those criteria. Signal Level (Input) Linguistic Variables: Low (L), Medium (M), High (H).

2. Rule Evaluation

After fuzzification, fuzzy logic rules are defined. These rules determine how the input linguistic variables affect the output linguistic variables (i.e., the gain that should be applied). Examples of rules might include. If the input is "low", then the output gain is "high". If the input is "medium", then the output gain is "medium". If the input is "high", then the output gain is "low".

3. Defuzzification

The final step is to convert the fuzzy values of the output variables back into concrete numerical values or applicable results. This defuzzification process converts the fuzzy inference results into concrete gain values that will be applied to the output signal. The fuzzy results obtained from inference need to be defuzzified to produce concrete or numerical values for the output gain. One common defuzzification method is the centroid method:

$$\text{Gain output} = \frac{\text{output} \times \text{degree of membership}}{\text{degree of membership}}$$

Where:

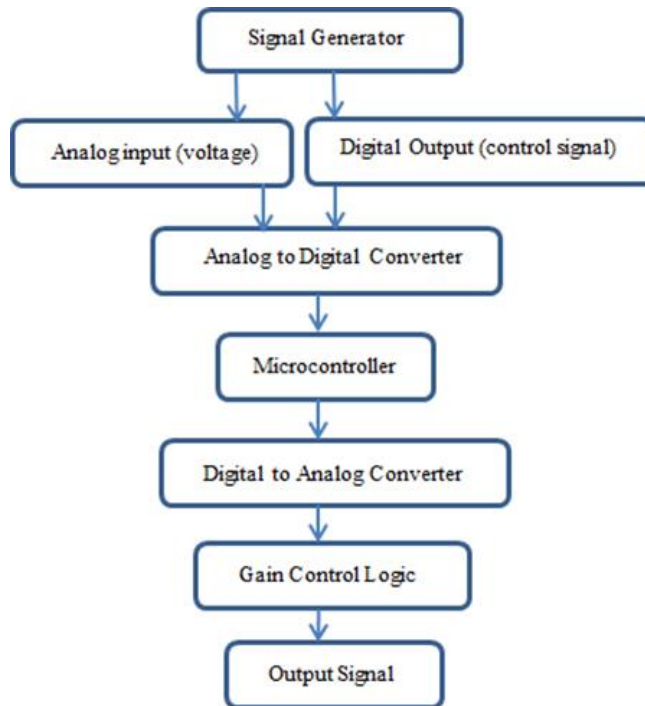
Output is the gain value for each fuzzy set (Low, Medium, High), and Degree of Membership degree of membership is the membership value given by the inference results.

METHODOLOGY

The system designed consists of Signal Analyzer Device DGC-optimized device to improve measurement accuracy. Function Generator Generates input signals with various shapes and frequencies. Microcontroller For signal processing and dynamic gain adjustment. Implementation of Function Generator Settings Generates sinusoidal, triangular and square signals with various frequencies and amplitudes. Microcontroller Programming Implementing the DGC algorithm on the microcontroller (ATX mega 128) to adjust the gain

automatically. Calibration and Testing Calibrate the signal analyzer device and carry out tests with input signals from the function generator.

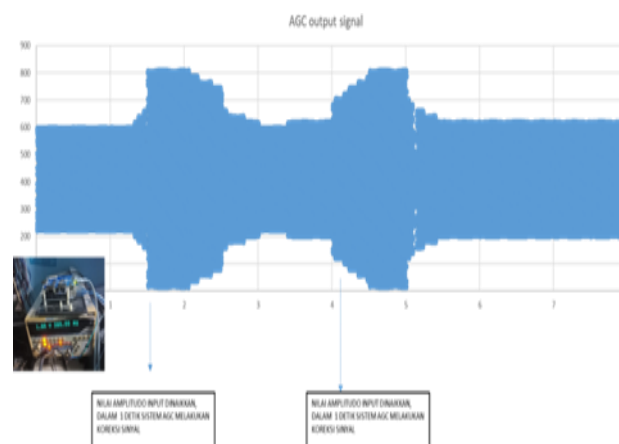
Assessment Parameters: Measurement Accuracy Assesses the extent to which the signal measurement with DGC is close to the actual value. Response Time The time required for the system to adjust gain to signal changes. System Stability The ability.



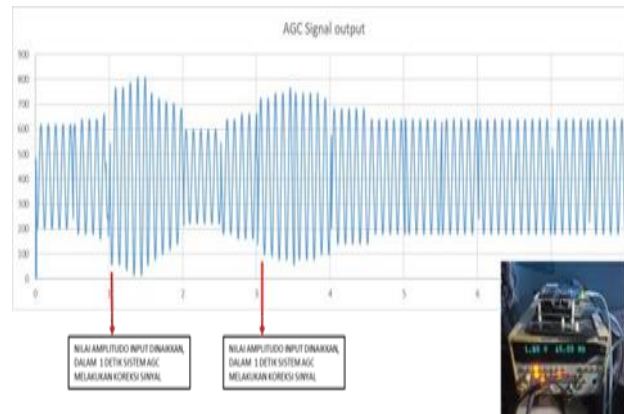
Picture 1. Research Flow

RESULTS

Experimental results on the AGC system with changed input amplitude and a fixed frequency of 200 Hz.



Picture 2. AGC system with changed input amplitude (200 Hz)



Picture 3. AGC System with Changed Input Amplitude (10 Hz)

DISCUSSION

Dynamic gain control of signal generators using microcontrollers is an important technique in modern electronics applications. The following are some conclusions that can be drawn from this dynamic implementation of gain control. Flexibility and Customization: The use of a microcontroller allows dynamic gain adjustment according to changing input conditions. This allows the system to adjust the signal output level according to the needs of a particular application. Ease of Integration: Microcontrollers often have the ability to interface with multiple sensors or other control systems, allowing the implementation of dynamic gain control as part of more complex systems.

Precision and Stability: Digital implementation using a microcontroller can increase precision in controlling gain, as well as ensure better stability of the output signal compared to traditional analog methods. Adaptation to Input Variations: By utilizing microcontroller programming features, the system can respond quickly to changes in input signal levels, optimizing signal output in an efficient and timely manner. Applicability in Various Applications: Dynamic gain control using microcontrollers is widely applied in various applications, including in the audio industry, instrumentation, measurement, and automatic control systems. Cost and Space Reduction: Implementations using microcontrollers are often more efficient in terms of cost and physical space compared to analog approaches that require additional complex components.

CONCLUSIONS AND RECOMMENDATIONS

According to the results obtained, the Amplitude value with dynamic value variations and taken at a certain frequency has a very small error value, but repeated experiments must be carried out for various frequency and amplitude ranges.

FURTHER STUDY

1. Formal academic style:

Further studies are recommended to examine the implementation of more adaptive Dynamic Gain Control in signal analyzer equipment, in order to improve measurement accuracy over a wide signal dynamic range.

2. *Technical-applicative style:*

Further research can be focused on the development of artificial intelligence-based Dynamic Gain Control algorithms that are able to optimize the sensitivity and stability of signal analyzers to signal amplitude fluctuations.

3. *Practical problem-based style:*

Further studies are still needed to minimize the effects of noise and distortion caused by the Dynamic Gain Control process, especially on signal analyzers used in measuring weak or rapidly oscillating signals.

4. *Explorative style:*

For future development, Dynamic Gain Control in the signal analyzer can be further explored through integration with the automatic calibration system to improve the consistency of measurement results in various environmental conditions.

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