Improved Automatic Gain Control Circuit Using Fuzzy Logic

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Abstract. A problem that arises in most communication receivers concerns the wide variation in power level of the signals received at the antenna. These variations cause serious problems which are usually be solved in receiver design by using Automatic Gain Control (AGC). AGC is achieved by using an amplifier whose gain can be controlled by using external current or voltage. We have to note that the AGC circuit does not respond to rapid changes in the amplitude of input and multifrequency. Nowadays, with the development of the fuzzy theory, the advantages of the fuzzy logic are recognized widely and deeply. Applying fuzzy logic to AGC circuit is a way to enhance AGC circuit.

1 Introduction

A problem that arises in most communication receivers concerns the wide variation in power level of the signals received at the antenna. This variation is due to a variety of causes. For example, in a space-communications system the satellite or spaceship transmitter may be continuously altering its position with respect to the ground receiver. In receiver design these variations cause serious problems which can usually be solved by using automatic gain control (AGC)[1][2]. AGC is one method to adjust automatically the gain of the amplifier circuit according to the intensity of signal by an external current or voltage. The design is superior but it is not adapted to the fast, wide range changing signal and different frequency signal due to the existence of capacitor. For example, radio as one kind of receiver can receive different frequency signals. However, for the fixed capacitor, AGC circuit can not adapt itself to different frequency. We can solve the problem using fuzzy logic algorithm (FLA). Fuzzy Logic is a paradigm for an alternative methodology which can be applied in developing both linear and nonlinear systems for embedded control [3]. In this case, using FLA, it is not needed to calculate exactly the signal relation between input and output. This paper is organized as follows: In section 2, the configuration of AGC circuit is introduced. The improved AGC system using fuzzy logic is designed in section 3, simulation results are shown in section 4. Finally, conclusions are presented in section 5.

L. Wang et al. (Eds.): FSKD 2006, LNAI 4223, pp. 159 – 168, 2006.

2 AGC Circuit

2.1 Theory of Automatic Gain Control

Commercially available AGC circuits, such as the LM13600 AGC amplifier, employ a basic control current source within an OP-amp, as shown in figure 1. In this circuit transistor T3 act as the constant-current source supplying current I_{AGC} [1], where

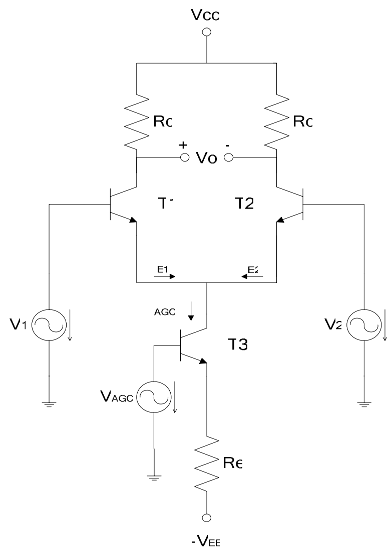

Fig. 1. A gain-control difference amplifier

$$I_{AGC} = \frac{V_{AGC} - 0.7 + V_{EE}}{R_e} \tag{2-1}$$

Using the small signal emitter currents analysis, we can know that the output voltage of v_o (setting $v_1 = 0$) is

$$v_o = (\frac{R_c}{2V_T} I_{AGC}) v_2(t) \tag{2-2}$$

If $v_2(t) = v_{2m}(t)\cos\omega_0 t$, then the amplitude voltage of the output is kept constant.

If we arrange to have I_{AGC} inversely proportional to the envelop of the input voltage,

$$I_{AGC} = \frac{K}{V_{2m}(t)} \tag{2-3}$$

Then (2-2) becomes

$$v_o = (\frac{R_c K}{2V_T}) \frac{v_{2t}}{v_{2m}(t)} \tag{2-4}$$

From (2-4), we can know that output is not depended on input signal.

2.2 Calculation of the Output Voltage of the AGC System

The output voltage v_{o1} of the gain-controlled op-amp A_1 shown in figure 2 [1].

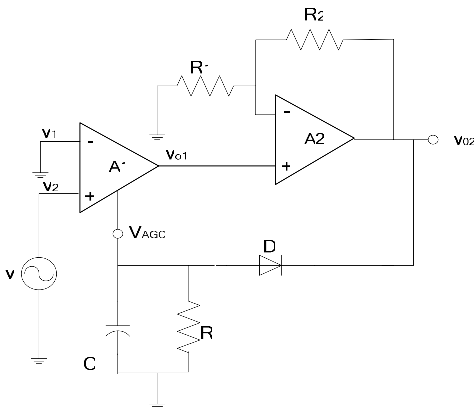

Fig. 2. Simple AGC system

$$v_{o1} = (\frac{R_c K_1}{2V_T} I_{AGC}) v_i \tag{3-1}$$

The output voltage v_{o2} of the entire AGC amplifier is then

$$v_{o2} = (\frac{R_c}{2V_T} K_1 K_2 I_{AGC}) v_i \tag{3-2}$$

where $K_2 = 1 + R_2 / R_1$, the gain of amplifier A_2. The output voltage $v_{o2}(t)$ is envelope detected so that the AGC voltage V_{AGC} is negative voltage. If $v_i(t) = V_{im}(t) \cos \omega_0 t$ and $v_o(t) = -V_{o2}(t) \cos \omega_0 t$, the AGC voltage can be shown as

$$V_{AGC} = -V_{o2m}(t) = -(\frac{R_c}{2V_T} K_1 K_2 I_{AGC}) V_{im}(t) \tag{3-3}$$

The gain-control voltage and current are also related by (2-1). Substituting (3-3) into (2-1) and solving for I_{AGC} yields.

$$I_{AGC} = \frac{V_{EE} - 0.7}{R_e + (R_c / 2V_T) K_1 K_2 V_{im}(t)} \tag{3-4}$$

The gain-control voltage and current are also related by (2-1). Substituting (3-3) into (2-1) and solving for I_{AGC} yields.

$$v_{o2} = (\frac{R_c}{2V_T} K_1 K_2) \frac{V_{EE} - 0.7}{1 + (R_c / 2V_T R_e) K_1 K_2 V_{im}(t)} \tag{3-5}$$

The gain K_1 and K_2 are usually made large enough to ensure that

$$\frac{R_c}{2V_T} K_1 K_2 >> 1 \tag{3-6}$$

Finally

$$v_{o2} \approx (V_{EE} - 0.7) \frac{v_i(t)}{V_{im}(t)} \tag{3-7}$$

This important result indicates that v_{o2} is proportional to $v_i(t)/V_{im}(t)$. This ratio has a constant envelope since the envelope of $v_i(t)$ is $V_{im}(t)$. As a result of the peak-detector action the AGC circuit responds only to slowly varying changes in the envelope to changes in signal power. A typical value for the RC time constant of the peak detector is 1sec [1].

It is interesting to note that the AGC circuit does not respond to rapid changes in the amplitude of v_i. If the amplitude of v_i were to change instantaneously, then even if OP-amps could follow the change, the envelop detector capacitor could not, since the capacitor's voltage could not change instantaneously. Hence, in response to such a change, (3-6) no longer applies and $v_{o2}(t)$ is proportional to $v_i(t)$ until steady state is reached. Thus, an AGC circuit is considered a "slow-acting" limiter. Otherwise, the peak value detector is useful for just one frequency because of the fixed RC circuit. Therefore, the two disadvantages make the AGC system tremendously limited.

2.3 One Example of AGC System in Practice

Fig. 4 shows a good example of AGC circuit which gets the I_{AGC} by feeding back circuit. We can see that if the output is big enough the Q1 passes. Therefore, a corresponding I_{AGC} to get the voltage of the V_{AGC} point goes down to make the input point current decreases, so the output I_{AGC} keeps the same level. On the other hand, if the output decreases, the function can make the voltage of the V_{AGC} goes up to maintain the output the same level [3].

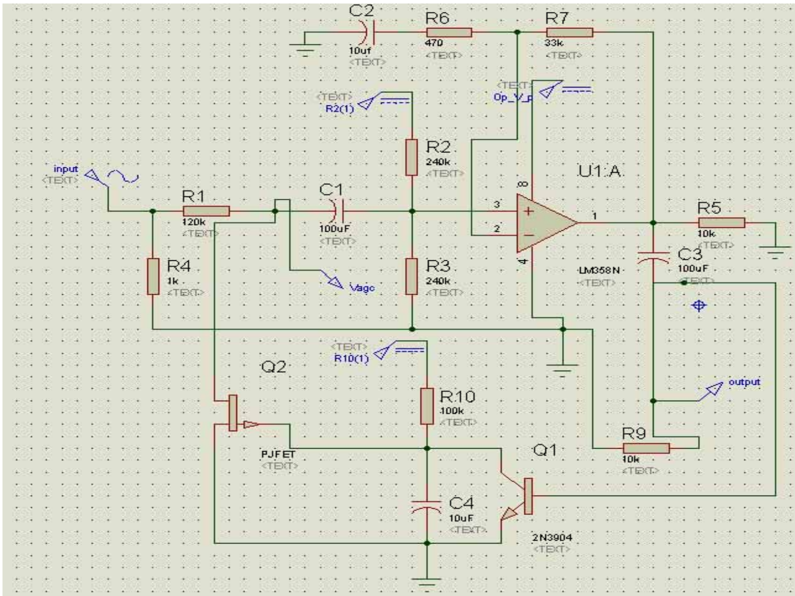

Fig. 4. Simulation of the AGC Circuit

2.4 Problem of the AGC Circuit

Referring to the figure 4, Q2, coupled with R2 and the equivalent resistance of R3 and R4, form a voltage divider to the input signal source. With input levels below 40mv p-p, the input is evenly divided between R2 (120k) and R3||R4 (120k). The output amplitude of LM358 isn't large enough to turn on Q2, which acts as a positive peak detector. The gate of the JFET is pulled to +5V, pinching its channel off and creating a very high resistance from drain to source. This essentially removes it from the circuit.

At input levels above 40mv p-p, Q1 is turned on at the positive peaks of the output of LM358, lowering the JFETs gate to source voltage. The channel resistance decreases and attenuates the input signal to maintain the output at approximately 1.2V p-p.

3 Improved AGC System Using Fuzzy Logic Algorithm (FLA)

3.1 Block Diagram of Conventional AGC System

Figure 5 shows the block diagram of the conventional AGC system which has been described in previous section and figure 6 shows the proposed AGC system. Fuzzy logic describes complex systems using knowledge and experience by fuzzy rules. It does not require system modeling or complex math equations governing the relationship between inputs and outputs. To overcome the problems of AGC circuit that discussed in previous section, we just need to change the envelope detector part by FLA. And we need not to calculate strictly the relation between the input and output voltage.

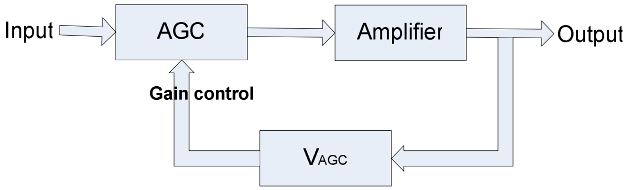

Fig. 5. Conventional AGC System

3.2 Improved AGC System

The example shown in figure 4 can be constructed as shown in figure 6. Use the FLA to replace the RC envelope detector part of conventional AGC.

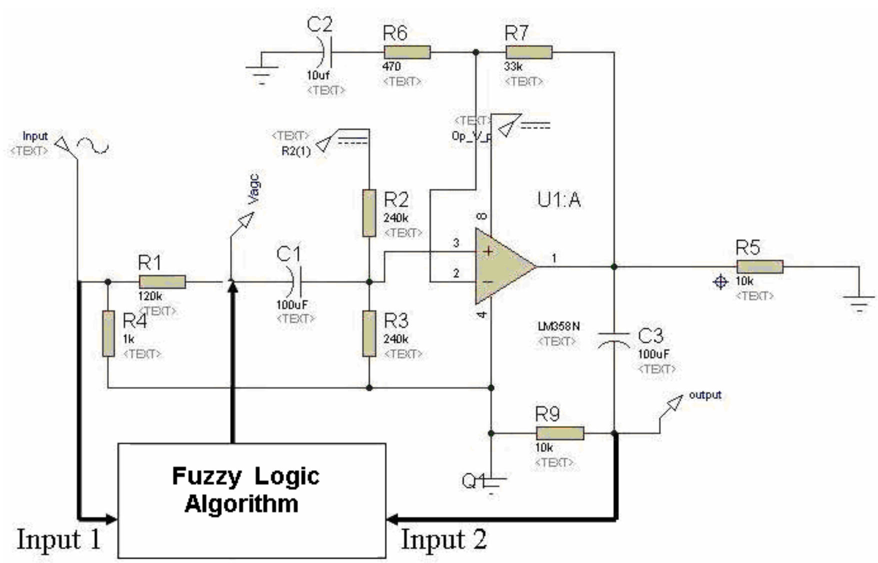

Fig. 6. Improved AGC circuit Using FLA

3.3 Construction of the Fuzzy Logic System

Determination of the state variables and control variables:

(a). state variables (the input variable of the FLC)
 -the input of the circuit, the output of the circuit
(b). control variable (the output variable of the FLC)
 -Vagc

Using Matlab 7.0 we can make the fuzzy rule and get the output. The input1 of the fuzzification is the input of AGC circuit, the input2 is the output of AGC [1],[2].

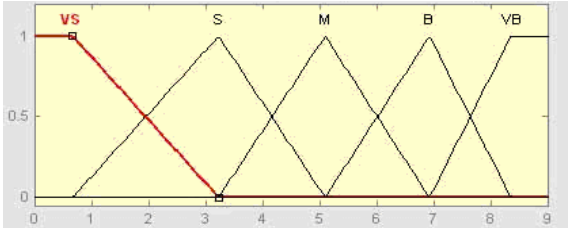

Fig. 7. Input1

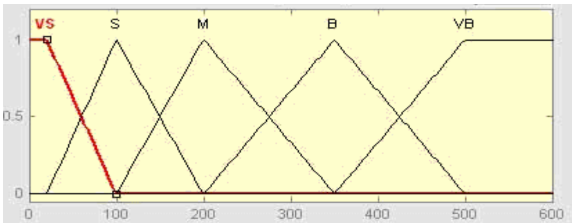

Fig. 8. Input2

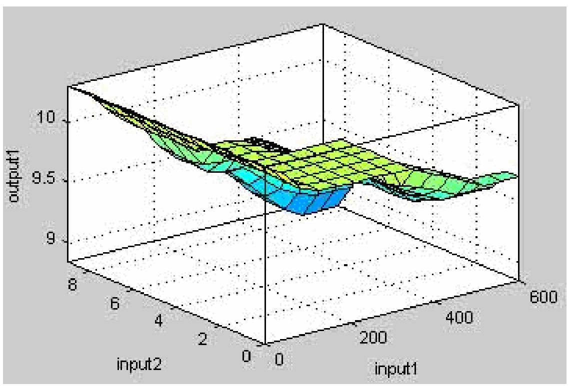

Fig. 9. Output surface

Use the input and output of the AGC circuit as the fuzzy input, and by correct fuzzy rules, we can get the Fuzzy Logic Controller output-gain control signal- Vagc.

4 Computer Simulation

4.1 Simulation of the Conventional AGC Circuit

In the Proteus 6 Professional which is a kind of circuit simulation tool, we can simulate conventional AGC circuit conveniently. Figure 4 is drawn using Proteus. After get the circuit pass, input a suitable signal and run the program, we can get the result as shown in figure 10.

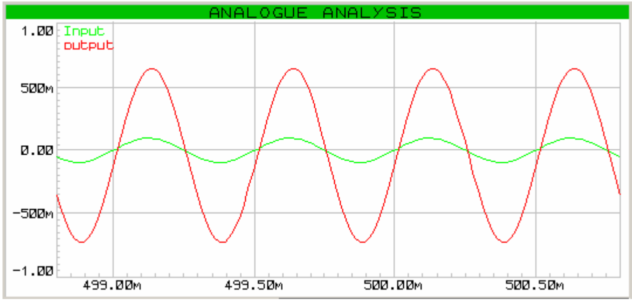

Fig. 10. Result of the Simulation

The green line (small signal) is the input signal and the red line (big signal) is the output signal. If we change the peak amplitude of the input signal at the period of 50mv ~ 1.2v, we can find the approximate output 650mv. When we apply the windows wave file (chord.wav) as the input signal, we get the following chart.

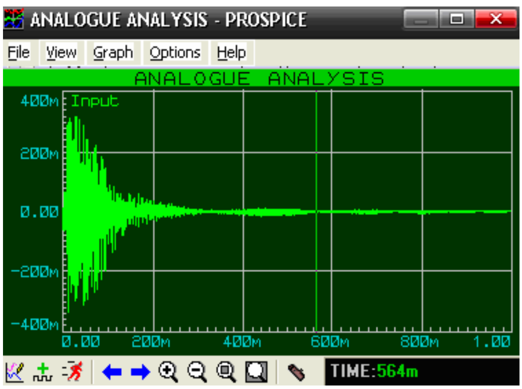

Fig. 11. The input of the Chord.wav

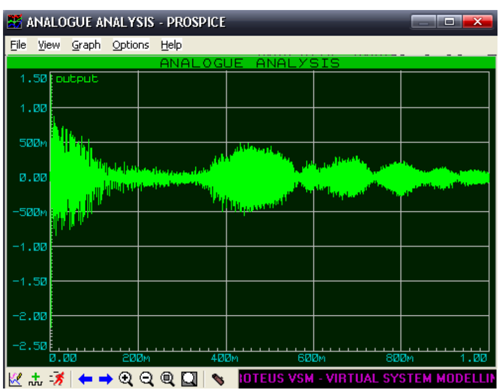

Fig. 12. The Output of the Chord.wav

From figure 12, we can see obviously that when the input signal is too small, the output can not be kept constant as what we have talked about before. So we can listen a short sound at the beginning of the signal but then there is no sound.

4.2 Simulation of the Improved AGC Circuit

Table 1 shows the data testing. Input one voltage signal and we can get the output in Proteus simulation. And then use the MATLAB fuzzy tool box what we have constructed fuzzy rule to calculate the Vagc control signal and then input the Vagc signal to the simulation circuit we can get the date testing table.

Table 1. Data testing

	V_{in}	V_{out1}	V_{AGC}	V_{out2}
1.	8mv	318mv	10.3mv	705mv
2.	70mv	2.47v	10.1mv	713mv
3.	230mv	5.55v	9.92mv	700mv
4.	379mv	7.28v	9.20mv	650mv
5.	463mv	8.01v	9.01mv	636mv

Then we simulate the No.3 data to get the figure following:

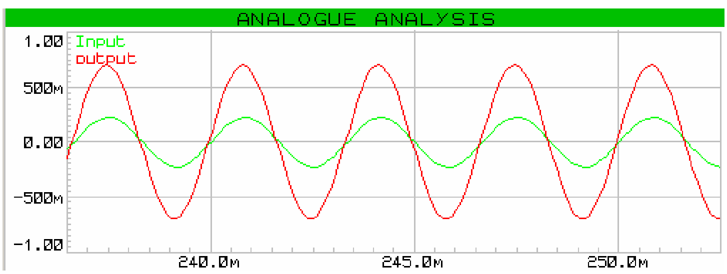

Fig. 13. Simulation Result

From this figure we can see that even the input signal is very small, the output is kept constant.

5 Conclusion

AGC circuit is an ingenious circuit and is used widely. In practice, capacitors are fixed to boards, so it is very hard to change the capacity of them. During the transmission of signals, there are too many unknown conditions affection. Therefore we have to find a way to increase the capacity of receiver part. When we add the FLA to AGC, we can make it more precise and efficient.

Acknowledgement

This work was supported by grant No. RTI04-01-02 from the Regional Technology Innovation Program of the Ministry of Commerce, Industry and Energy(MOCIE).

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