A Control Circuit Design for Automatic Aperture

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Abstract. In view of the fact that automatic aperture technique is applied as a method of regulating light in the current industrial monitoring and control systems more and more, an automatic aperture control circuit is designed according to automatic aperture control principle. The circuit has the characteristics of the simple structure, low cost and high reliability and etc. It has been proved by experiments that the circuit can adjust the size of aperture automatically according to the change of the external illumination, which ensures proper luminous flux entering the lens, and avoids the loss of image gray levels in bright space, and solves the image flicker caused by the change of light intensity, ensures the CCD get used to brightness changes of scenery outside and obtain the best image.

1. Introduction
In the optical lens of photoelectric imaging equipment such as industrial monitoring system, automatic aperture is widely used as dimming method. Aperture is an extremely important parameter of optical lens, usually in optical lens. The purpose of setting an automatic aperture in a lens is to control the amount of light flux into the lens by changing the aperture size in the environment where the target brightness and background change greatly [1]. Large aperture, high luminous flux; small aperture, low luminous flux, so that the CCD image surface can obtain appropriate illumination which can avoid causing halo image and burning target surface, ensure that the video signal output by CCD is clear and reliable, and prevent screen flicker and CCD saturation [2].

At present, the main driving and controlling methods of automatic aperture lens are video control and DC control. The interface of automatic aperture for video control uses three pins, including power supply, video and grounding. The DC control automatic aperture interface uses four pins, namely, damped positive con+, damped negative con-, driven positive DR+, and driven negative DR-. In this paper, a DC control circuit for automatic aperture DC control mode is designed and tested.

2. Basic Control Principle
The automatic aperture adjusts the aperture size mainly by controlling the motor rotation by controlling the circuit. The motor has two groups of coils, one group of driving coils and one group of damping coils. According to the illumination of the outside world, using the feedback of video signal, the driving coil is controlled by the control circuit to drive the motor to turn forward and backward, so that the diaphragm can be enlarged or reduced accordingly [3]. A schematic diagram of the relationship between aperture and illumination is shown in Figure 1.
When the external illumination becomes larger, the gray value of the video signal of CCD increases accordingly. If the signal voltage exceeds the prescribed value, the control circuit will generate the corresponding voltage to control the lens aperture and turn it down. Conversely, if the external illumination becomes lower, the control circuit will adjust the aperture to make it wider and maintain the appropriate light flux, so that the gray level of the video signal is kept at the prescribed value.

The damper coil is connected with a current sensor. If the aperture changes rapidly, the induced EMF on the damper coil is high. By controlling the circuit, the driving current is reduced, and the speed of the driving aperture is slowed down, and vice versa. Damping coils play a role in smoothing the control of the aperture.

3. Design Scheme
The purpose of the circuit design in this paper is to stabilize the brightness of the CCD image by controlling the aperture size so as to achieve the best image quality. According to the requirements of image processing, if the brightness of the image is basically stable, the gray value of the image is stable in a certain range \([4]\). However, due to various factors, the illumination received by CCD after aperture adjustment often causes the image gray value to be under-damped or over-damped, which can’t make the image gray value fast and stable in a certain range \([5]\). As shown in Figure 2.

In Figure 2, \(\tau\) represents the convergence time.

If the gray value is under-damped, the display image will flicker. If the gray value is in an over-damped state, the aperture can’t be opened quickly and completely. Only when the gray value is in the critical damping state, the gray value of the image can quickly converge to the desired value. The \(\tau\) smaller is, the faster the gray convergence of the image is, and the faster the gray stability of the image is.

In order to solve this problem better, the first-order closed-loop system is composed of automatic aperture and CCD. The system has good convergence performance, which can make the image gray
quickly converge to a fixed gray expectation value, and then stabilize the brightness of the image. The design scheme is shown in Figure 3.

![Design scheme](image)

**Figure 3.** Design scheme

The reflected light of the scene passes through the optical front lens, variable aperture and rear lens, and is imaged on the target surface of the CCD. The CCD converts the optical signal into electrical signal, processes it and outputs the video signal. When the illumination of external environment increases, the amplitude of video signal output from CCD increases. By comparing the feedback of video signal with the reference voltage, the circuit outputs the control signal, and the driving circuit detects the control signal to drive the motor, which reduces the aperture, the light flux of the lens and the video signal, and vice versa. When the reference voltage is fixed, with the change of external illumination, the system will automatically adjust the aperture by driving the motor in the lens to rotate forward and backward to achieve the purpose of adjusting the brightness of the image plane, so as to ensure a clear image.

4. Circuit Design

The automatic diaphragm DC control circuit block diagram is shown in Fig. 4.

![Circuit design diagram](image)

**Figure 4.** Circuit design diagram

The circuit is mainly composed of gray detection circuit, amplification circuit, reference voltage setting circuit, error magnification unit, driving circuit and impedance matching circuit.

The reflected light from the scene is projected onto the CCD photosensitive surface through the lens aperture. The CCD converts the light signal into electrical signal and processes it. The video signal (Video) is output. The output Video amplitude varies with the external illumination. Figure 5 shows the output waveform of Video in the absence of illumination, i.e. at low illumination. Figure 6
shows the output waveform of Video when illuminated by light, i.e. at high illumination. It can be seen that when the illumination is high, the Video amplitude is large, and vice versa.

Figure 5. Without light when the Video output waveform
Figure 6. With light when the Video output waveform
Figure 7. The detected gray value of Video signal

Video passes through a gray level detection circuit. After video separation and average detection, the average gray level is detected, as shown in Figure 7.

Because of the small amplitude of the gray mean signal, the amplification circuit is needed. The amplification factor should be determined according to the reference voltage. If the magnification factor is too large, it is easy to make the magnified gray mean signal (IRIS-in) change beyond the control range of the reference voltage (IRIS-set) and cause the aperture out of control. Therefore, the range of IRIS-in must be within the adjustable range of the reference voltage. Figure 8 shows the enlarged IRIS-in.

Figure 8. The amplified gray mean signal (IRIS-in)
Figure 9. Reference voltage setting circuit

The setting of IRIS-set is based on the circuit shown in Figure 9. The range of IRIS-set can be set by the parameters of R0, R1, R2 and R3. By adjusting potentiometer R1, the value of IRIS-set can be changed to achieve the goal of manually controlling the aperture.

The error magnification unit plays a key role in the control loop of the system. The gain of the circuit determines the damping state of the closed-loop control system during the stabilization process. The error amount amplifying unit compares the detected amplified gradation signal (IRIS-in) with a set desired voltage (IRIS-set), and outputs an error amount. When the error is greater than zero, the output signal V0 controls the driving circuit to drive the motor to rotate backwards, which reduces the aperture and the light flux into the lens. Video amplitude is reduced by optical feedback, thus IRIS-in is reduced. When the error is less than zero, V0 controls the forward rotation of the motor, which enlarges the aperture and increases the light flux into the lens. Video amplitude is increased by optical feedback, and then IRIS-in is increased until IRIS-in equals IRIS-set. As the feedback resistance of operational amplifier in this unit, Rf plays the role of adjusting the closed-loop damping of the control system, and can adjust the control circuit to the critical damping state.
While adjusting the diaphragm of the motor, the damper coil induces the electromotive force corresponding to the speed of the motor. At this time, the input end of op-amp is fed back by impedance matching circuit at both ends, and the driving current is adjusted, so that the opening and closing process of diaphragm can be smoothly carried out and the diaphragm size can be smoothly controlled.

The control system real-time adjusts aperture size of aperture to control light flux, so that the gray value of the image remains stable, so as to optimize the output image and achieve the purpose of automatic aperture adjustment.

5. Circuit Debugging
This paper adopts CCTV LENS lens, which is an automatic aperture and manual focusing lens. After the lens is connected to the designed control circuit, the debugging results are as follows:

5.1. Manual Aperture Control
When the external illumination is constant, only the potentiometer R1 is adjusted to maximize the IRIS-set from zero. At this time, with the increase of IRIS-set, the aperture increases from fully closed to fully open, and the light flux to the target surface of the CCD increases, and the brightness of the output image of the CCD increases. As shown in Figure 10.

Fig. 10 shows that IRIS-set is too small, aperture opening is small, the output image brightness of CCD is not enough, and the image is darker, as shown in Fig. 10 (a), 10 (b), 10 (c), 10 (d). When adjusting IRIS-set to make the aperture turn on completely and critically, the output image of CCD is clear and the quality is the best, as shown in Figure 10 (e). Continuing to increase IRIS-set, the output image brightness of CCD is too high, and the image picture effect is not good, as shown in Figure 10 (f).

5.2. Auto Iris Control
Contrast the same scene, change the external illumination. The test results are shown in Figure 11. Figure 11 (a) shows the image when the desk lamp is turned off. Figure 11 (b) shows the image when the lamp is on.
It can be seen that the aperture can automatically adjust the size according to the illumination of different external illumination, so as to avoid losing the gray level of the image in the light, and ensure the output of the best clear image.

Experiments show that the control circuit meets the requirements of automatic aperture control.

6. Summary
According to the principle of automatic aperture control, an automatic aperture control circuit is designed in this paper. The circuit has the characteristics of simple structure, low cost and high reliability. The experiment proves that the control circuit can automatically adjust the aperture under different illumination, keep the appropriate light flux in the lens, avoid losing gray level in the light, and solve the phenomenon of image flickering caused by the change of light intensity. The automatic aperture control can adapt to the change of the brightness of the external scenery very well, and make the CCD get the best picture effect.

7. References
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