

System Integration

Corning® Varioptic® Lenses can be used in several types of systems:

- Manual focus: the user adjusts the focus manually, with a knob for example
- Closed-loop: this is the standard auto focus method, where a processor runs a contrast optimization loop to maximize the sharpness of the image
- Open-loop: this is a mode where the focus command is directly sent to the lens, from an external distance measurement for instance
- Mixed mode: a combination of open loop for coarse search, and closed loop for fine tuning of the focus
- Sweep mode: this mode performs a continuous sweep of the full range of the optical power of the liquid lens

Closed-loop Auto Focus

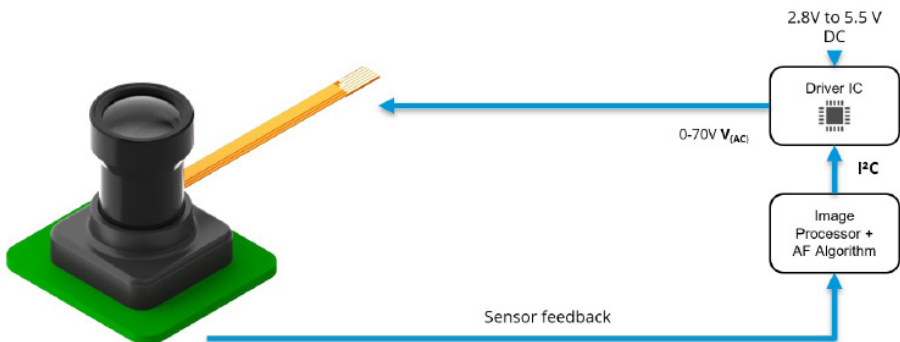
A closed-loop system consists of:

- An image sensor
- An optical lens consisting of fix-focus optics and an adjustable lens
- An adjustable lens driver IC
- A processor (ISP, FPGA...)

The processor performs the following tasks:

- Contrast measurement on the image output by the sensor
- Modification of the driver IC command to maximize this image contrast.

Corning Varioptic Lenses provides auto focus algorithms that have been optimized for the adjustable lens. The overall performance depends on many system parameters such as sensor frame rate and processing speed; typically, the complete auto focus loop can be completed in 8 to 12 frames.



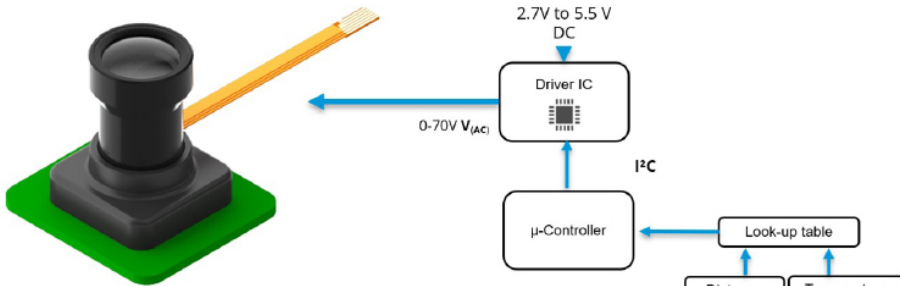
Open-loop Driving

Although the adjustable lens closed-loop is extremely fast, there are situations where it is not possible to acquire several frames to perform a focusing loop. In this case, the solution is to use open-loop focusing, where the sensor feedback is not used.

Open-loop focusing is based on a look-up table where the desired focusing distance is linked to the driver IC command. This look-up table is initially calibrated through an easy process since the lens response is linear and stable. Focusing is then triggered through an external external device, for instance:

- A distance measurement device (telemeter) that measures object position in real time
- A predetermined set of distances, etc.

Through the addition of this extra device, open-loop driving enables ultra-fast focusing where focus can be achieved within one frame only.



Closed-loop vs. Open-loop

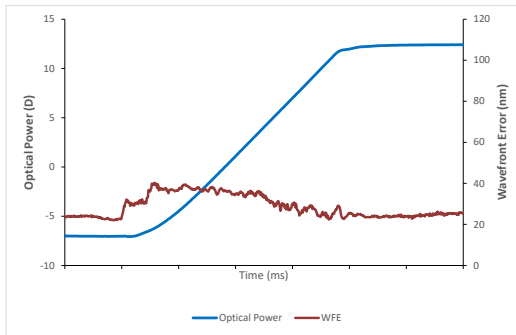
The main advantage of the closed-loop system is its simplicity of integration. Indeed, an open-loop system will need:

- A distance measurement device
- A temperature sensor
- A calibration of the device during production

Also, an open-loop system may be susceptible to any variation in the system. For optimum performances, open-loop and closed-loop should be combined: open-loop for coarse search and closed-loop for fine search.

Sweep mode

This mode is particularly suited for applications where the image does not need to remain in focus, typically like on the fly decoding applications. The focus ramp is a linear change of the optical power of the liquid lens with time, allowing the acquisition of images while the Liquid Lens is still moving, with virtually no settling time. The principle is to cover the full optical power range of the liquid lens such as having the focus moving between infinity and short distance making sure to have any targeted object focused at least on one image. The collected images can then be analyzed and decoded in parallel. This method can be extremely fast since it doesn't require any settling time between 2 focus positions relying on the unique property of the Liquid Lens which is, being able to provide high optical quality even while the optical power is being changed.



A-16F0 – Sweep example

Parameters can be tuned to meet application requirements (rise time, diopter range etc...).