A Memory Sharing Algorithm Compensation Scheme Combining De Burn-in and Demura for OLED Displays

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Abstract

Due to the limited capacity of the internal SRAM in Flash and TCON IC, the stored compensation data needs to be compressed as much as possible. However, the compression scheme will not only increase hardware resources but also affect the compensation effect due to the loss of data precision. Based on the working characteristics of the two algorithm IPs, Demura and DBI, this paper proposes a circuit design method that allows the two algorithms to share compensation data. This method can not only reduce hardware storage resources by approximately 33% but also achieve the effects of Mura external compensation and display aging compensation simultaneously.

Author Keywords

Memory Sharing; De Burn-in (DBI); Demura; Compensation Data Conversion

1. Introduction

In recent years, the application range of AMOLED displays has expanded to scenarios such as smartphones, laptops, and automobiles. AMOLED displays have advantages such as high contrast, wide color gamut, and being thin and light. However, as the process difficulty of displays has increased, deviations in manufacturing process control can easily lead to poor screen uniformity. Demura is a commonly used external compensation method to solve the problem of uneven screen brightness. Panel manufacturers obtain Mura optical data by photographing the panels. After being processed into Demura compensation data by algorithm software, these data are stored in Flash. This data corresponds to each panel one-to-one and is equipped with the panel's Flash. During the display process, the DDIC retrieves the compensation data through the Demura IP to improve the display effect.

In addition, due to the limitations of OLED light-emitting materials in terms of efficiency decay and lifespan, as well as the deviations in manufacturing process control, different degrees of decay of sub-pixels may occur. Under normal circumstances, the degree of decay of sub-pixels is very slight, but there is a difference in the decay rate between bright areas and dark areas. If the screen brightness difference is large and the image stays for too long, the brightness difference after decay will become more and more obvious, which may lead to the "burn-in" phenomenon, also known as long-term afterimage. The De Burn-in (DBI) compensation algorithm is used to solve the technical problem that as the screen usage time increases, the screen brightness will decrease and form afterimages, thereby affecting the display effect. During display, the IP will continuously accumulate the aging data of sub-pixels, store it in the internal SRAM of the TCON IC, update it to the Flash at a certain frequency, and perform aging compensation to ensure that the display effect of the screen remains consistent from T0 to Tn.

Due to the limitations on the size of internal SRAM in Flash and TCON IC, both Demura data and DBI data need to be compressed as much as possible, and Block compression and Data compression are usually used. The compression scheme will not only increase hardware resources but also affect the compensation effect, leading to problems such as poor compensation effect.

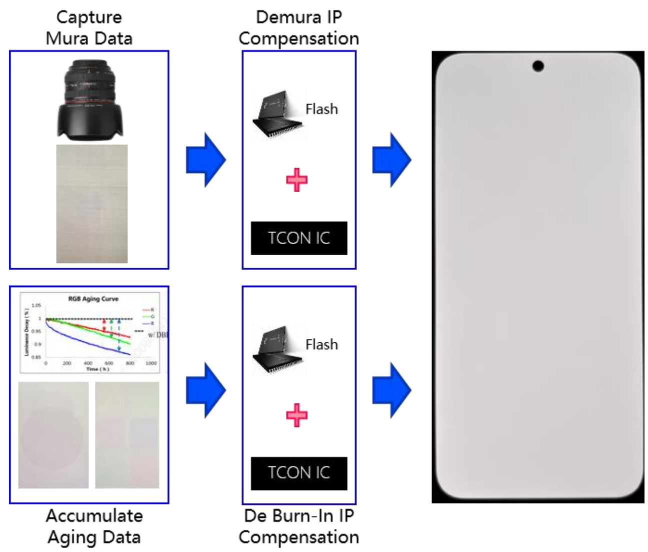

Figure 1. Principle of Demura & De Burn-in Algorithm

As shown in Figure 1, the display screen usually achieves the optimal display effect under the combined action of Demura IP and DBI IP. It is easy to find that both the Demura and DBI algorithm IPs need to retrieve compensation data from Flash to TCON SRAM for compensation calculations during display. The difference is that Demura retrieves the Mura compensation data obtained by photography, while the DBI algorithm retrieves the aging compensation data accumulated by the TCON IC. Therefore, this proposal puts forward an algorithm architecture scheme in which the two algorithms share compensation data according to the working characteristics of the two algorithm IPs, Demura and DBI, thereby reducing the internal SRAM of Flash and TCON IC.

2. Methods

The working Methods of optical De-Mura is shown in Figure 2, which is presented in the following four steps. First, capture raw data of under different grayscale levels by industrial camera, including focusing, aperture settings, and exposure time settings. Then, convert the raw data into brightness data for each sub-pixel, including flat field correction, mapping, removing noise. And the next, generate offset data from the brightness data, compress the offset data, and send this data and parameters to the flash memory. Finally, use Demura IP and parameters to calculate the compensation data under all DBV and Gray levels based on the offset data and the display data. The existing optical Demura usually performs Mura acquisition and compensation for each display, under normal circumstances, compensation offset data will occupy more than 8M of storage resources in the flash and TCON SRAM.

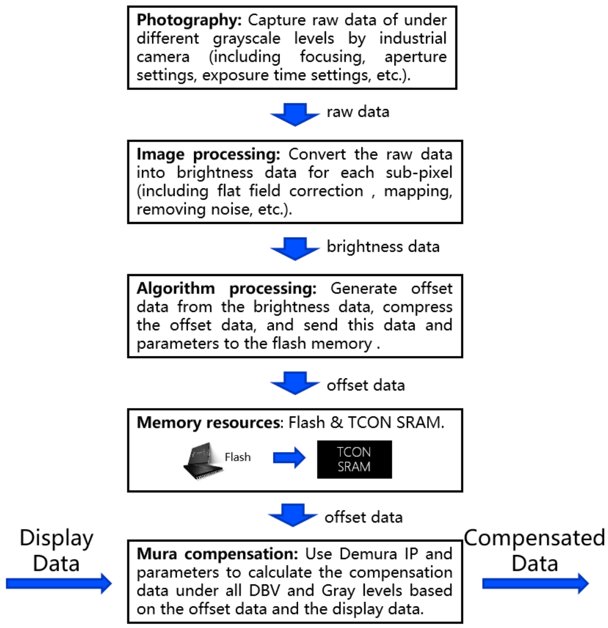

Figure 2. Flow of Optical Demura.

Figure 3 illustrates how the compression method is linked with DBI. Implementation process of the de burn-in algorithm: collect the current display status of the screen at fixed intervals and accumulate it into the aging data, the RAM will back up the burn-in data to the Flash at fixed intervals, the burn-in data is stored in the RAM of TCON or DDIC, Compensate the current display content according to the aging data and parameters in the SRAM,

The RAM will back up the burn-in data to the Flash at fixed intervals. To be able to record longer aging lifespans, a space of more than 20 bits is usually used to record the lifespan data of a single unit. At the same time, in order to improve the recording accuracy as much as possible and reduce the area of a single unit, the total hardware storage resources used are more than 16M.

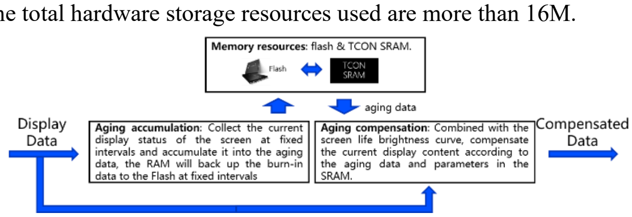

Figure 3. Flow of De Burn-in.

Based on the working characteristics of the two algorithm IPs, Demura and DBI, this paper proposes a circuit design method in which the two algorithms share compensation data, thereby reducing the resources of Flash and the internal SRAM of the TCON IC. Flow of this method is shown in Figure 4. After capturing images to obtain Mura data, during the processing by the algorithm software, the sub-pixel brightness data is directly converted into initial aging data. The aging data is compressed, and this data along with parameters are sent to the flash memory. During display, the accumulated sub-pixel aging data is continuously updated to the same space in the flash memory. Finally, display compensation is achieved by combining the brightness attenuation characteristics. In the case of sharing compensation data, not only can hardware storage resources be reduced by approximately 33%, but also the effects of Mura external compensation and display aging compensation can be achieved simultaneously.

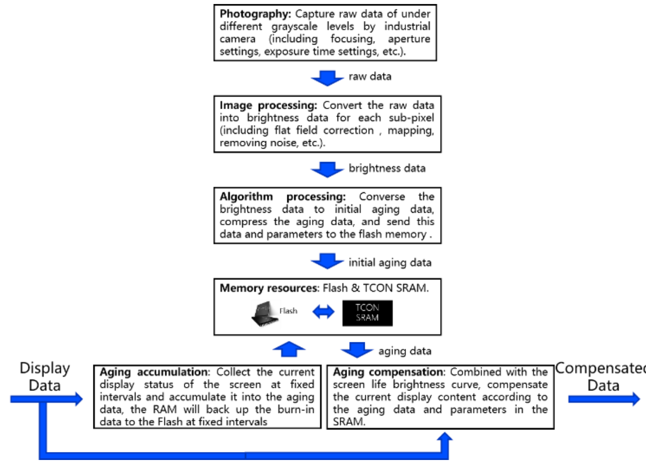

Figure 4. Flow of the Memory Sharing Compensation

2.1 Compensation Data Conversion Model

Many OLED degradation models have been proposed in previous studies, among which the stretched exponential decay (SED) model [1] [2] is widely accepted. In specific scenarios, some more accurate models are designed based on the SED model [3]. The SED model describes the relationship between OLED brightness and light-emitting time, and its expression is shown in Eq. (1).

$$\frac{L}{L_0} = exp\,[-\left(\frac{t}{\tau}\right)^{\beta}] \qquad (1)$$

Here, L_0 is the initial brightness of the OLED; τ is the time scale of decay; β is the stretch exponent. The brightness of the OLED can be estimated by τ and β, which are extracted from the measured L-T curve of the OLED panel.

The L-T curve shows the relationship between OLED brightness degradation and measurement time, and its derivative is defined as the degradation rate. In this scheme, an approximate curve model is also used for the conversion between brightness and lifetime, as shown in Figure 5.

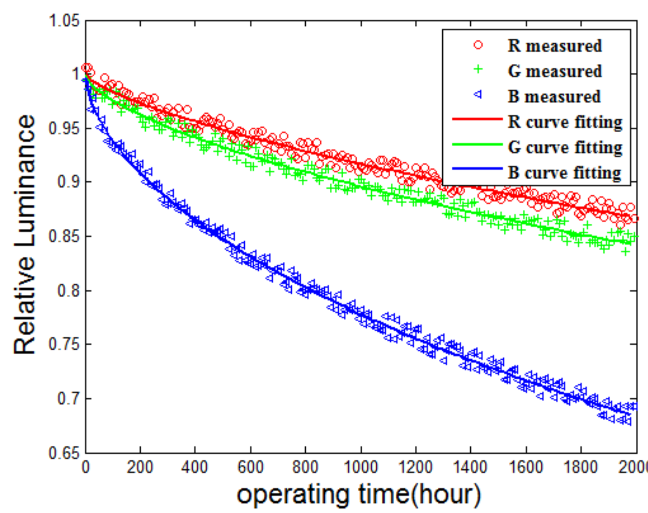

Figure 5. L-T curve, OLED Luminance vs. Measurement Time [4]

Generate compensate offset data from brightness data, converse offset data to initial aging data, compress aging data, send this data and parameter to OLED display Flash. Compensation based on the life curve, conversion relationship is shown in Figure 6. The lower the initial brightness of a sub-pixel, the longer its initial lifespan and the higher the compensation amount.

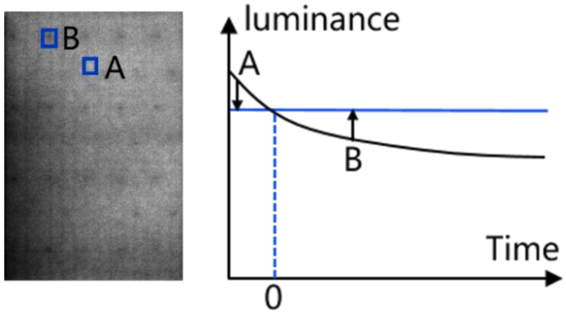

Figure 6. Schematic Diagram Compensation Data Conversion Model.

What's special is that, because some pixels need to have their brightness reduced, the initial lifespan, with reference to the real curve, has an additional negative lifespan segment.

2.2 Data Compression Model

Due to the limitations on the size of internal SRAM in Flash and TCON IC, both Demura data and DBI data need to be compressed as much as possible, and Block compression. As shown in Figure 7, using 2×2 Block compression.

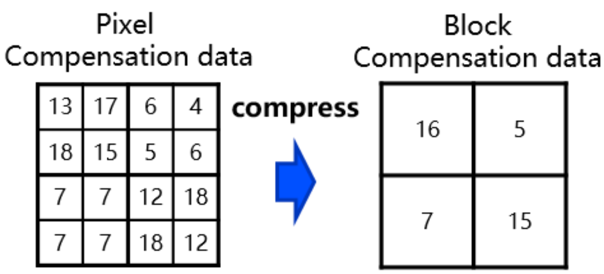

Figure 7. Schematic Diagram of Block Compression.

Take the average of the compensation data of the 4 sub-pixels in a block, which is the block compensation offset value, and store it in the flash. When displaying compensation, the 4 sub-pixels in the block are compensated using the same compensation offset value.

However, in the process of data accumulation, when using the block method for accumulation, especially when the V block Size is not 1, a larger line buffer is required, thus leading to higher demand for hardware resources. To reduce hardware resources, this algorithm adopts the method of intra-block frame cycling for data accumulation, and the specific scheme is shown in Figure 8.

By adopting this method of accumulating data through intra-block frame loops, within each frame, it is only necessary to calculate the aging value of one sub-pixel based on the displayed data (dividing the display data by 4 to obtain aging value is shown in the Figure 8) and accumulate it to the aging life.

For example, if the lifetime accumulation plan records aging data every 5 seconds, and the compressed block size is set to 4 by 4, then 16 times of aging data will be collected evenly within 5 seconds. Each collection is the original pixel data divided by 16, so that the average aging data of all sub-pixels in the block within 5 seconds can be calculated.

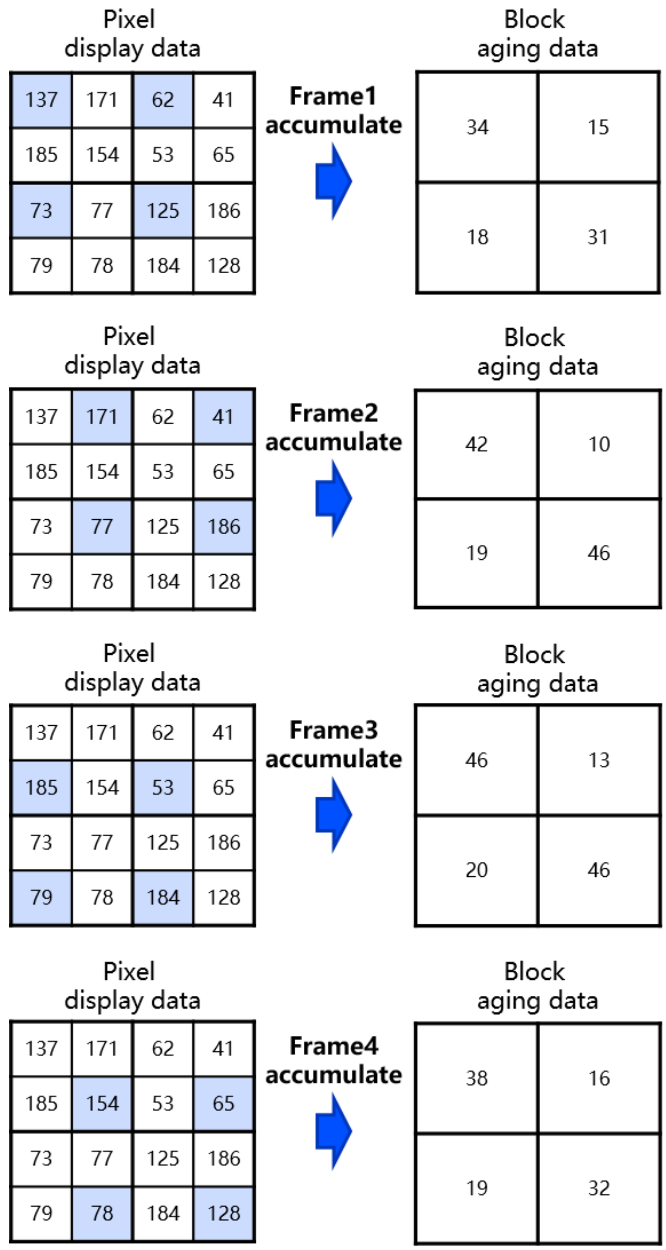

Figure 8. Schematic Diagram of Block Accumulation.

Therefore, the V block size is not limited, and it can flexibly adapt to various compression ratio requirements.

2.3 Manual Correction of Aging Data

In fact, due to the influence of craftsmanship and device performance, the aging curves of the service life of different screens vary greatly. Therefore, a secondary collection method can be adopted to calibrate the aging data, and the specific process is shown in Figure 9.

After a period of use, the actual accumulated aging value of each pixel can be updated by taking new photos, and the brightness compensation coefficient can be updated simultaneously to achieve a better compensation effect.

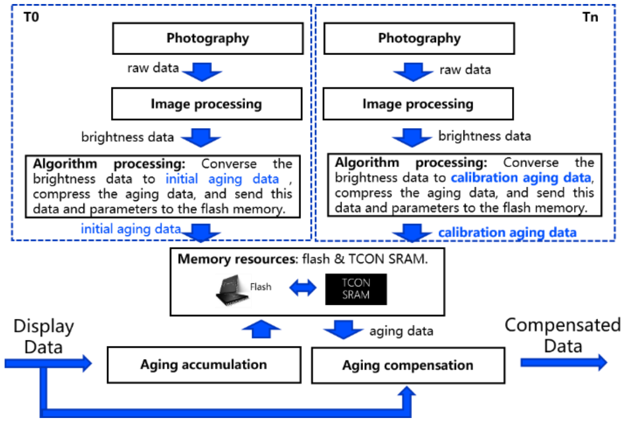

Figure 9. Flow of Manual Correction

3. Experiments and Results

In the conventional scheme, as shown in Figure 10, the Mura data obtained by the camera is usually converted into 8M offset data, while the conversion of display data continuously accumulates into 16M aging data, which in total occupies 24M of storage resources. However, in the storage sharing compensation algorithm proposed in this paper, the Mura data is directly converted into 16M aging data, and the storage space is shared with the aging data converted from the display data, using a total of 16M storage resources, which saves 33% compared with the original scheme.

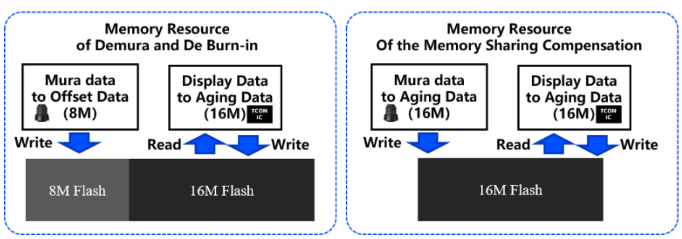

Figure 10. Memory Resource Reduction

This compensation method has been verified using an FPGA. As shown in Figure 11, a 6.6-inch AMOLED display module with a resolution of 1264×2800 was driven and lit up based on Xilinx's VCU118 development board. The PC side sends aging patterns through an adapter board, and the FPGA on the development board implements algorithm compensation.

Figure 11. Experiment System

In order to quickly verify the proposed compensation method, an aging pattern (as shown in Figure 12(a)) is displayed on the screen of the OLED panel during hundreds of hours continuously under high-temperature conditions.

(a) (b) (c) (d)

Figure 12. (a) Aging pattern for experiment. (b) Gray level image in initial OLED panel without compensation. (c) Gray level image in aged OLED panel without compensation. (d) Gray level image in aged OLED panel with compensation.

As shown in Figure 12(b), before the aging test, an obvious Mura pattern can be seen when all pixels display the same gray level of 64. After the aging test, the increased screen burn-in is quite obvious. We can clearly identify the outline of the test image in Figure 12(c), but after applying the proposed compensation method, the screen burn-in in Figure 12(d) disappears.

4. Conclusion

This paper proposes a circuit design method based on the working characteristics of Demura and DBI, in which the two algorithms share compensation data, thereby reducing the resources of Flash and the internal SRAM of the TCON IC. After capturing images to obtain Mura data, during the processing by the algorithm software, the sub-pixel brightness data is directly converted into initial aging data. The aging data is compressed, and this data along with parameters are sent to the flash memory. During display, the accumulated sub-pixel aging data is continuously updated to the same space in the flash memory. Finally, display compensation is achieved by combining the brightness attenuation characteristics. In the case of sharing compensation data, not only can hardware storage resources be reduced by approximately 33%, but also the effects of Mura external compensation and display aging compensation can be achieved simultaneously.

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