# Rawgment: Noise-Accounted RAW Augmentation Enables Recognition in a Wide Variety of Environments

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# Outline

- Introduction
- Framework
- Method
- Experiment
- Conclusion

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# CMOS Active Pixel Structure

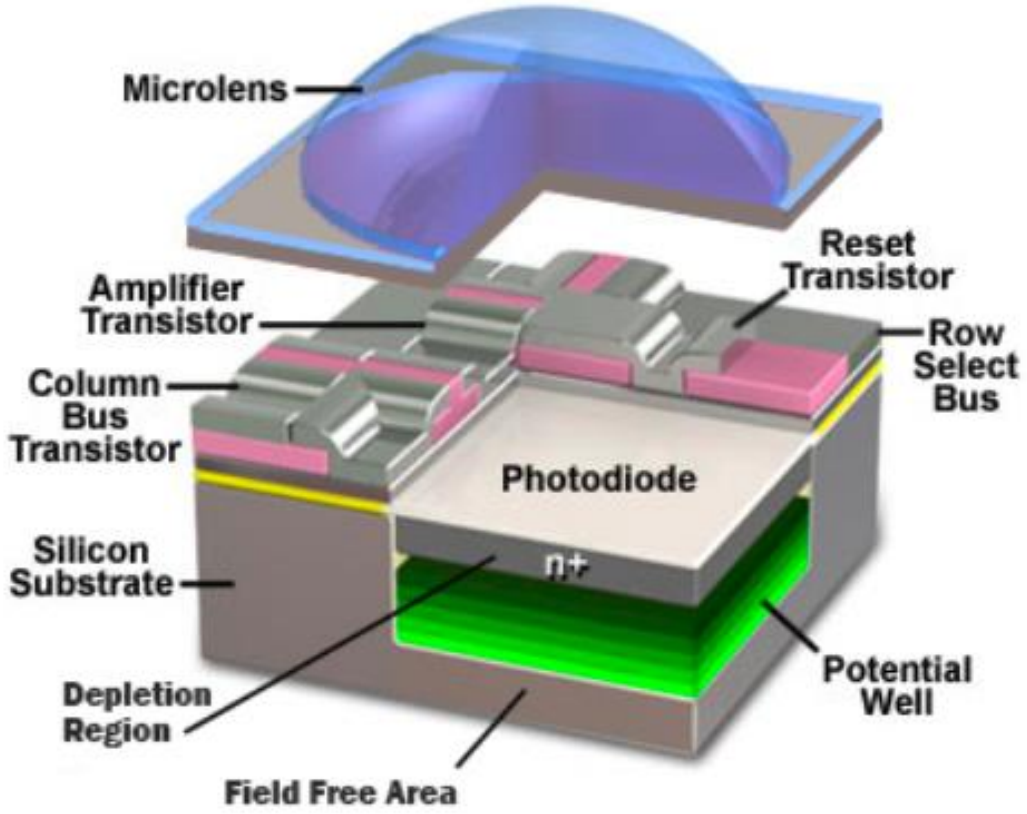
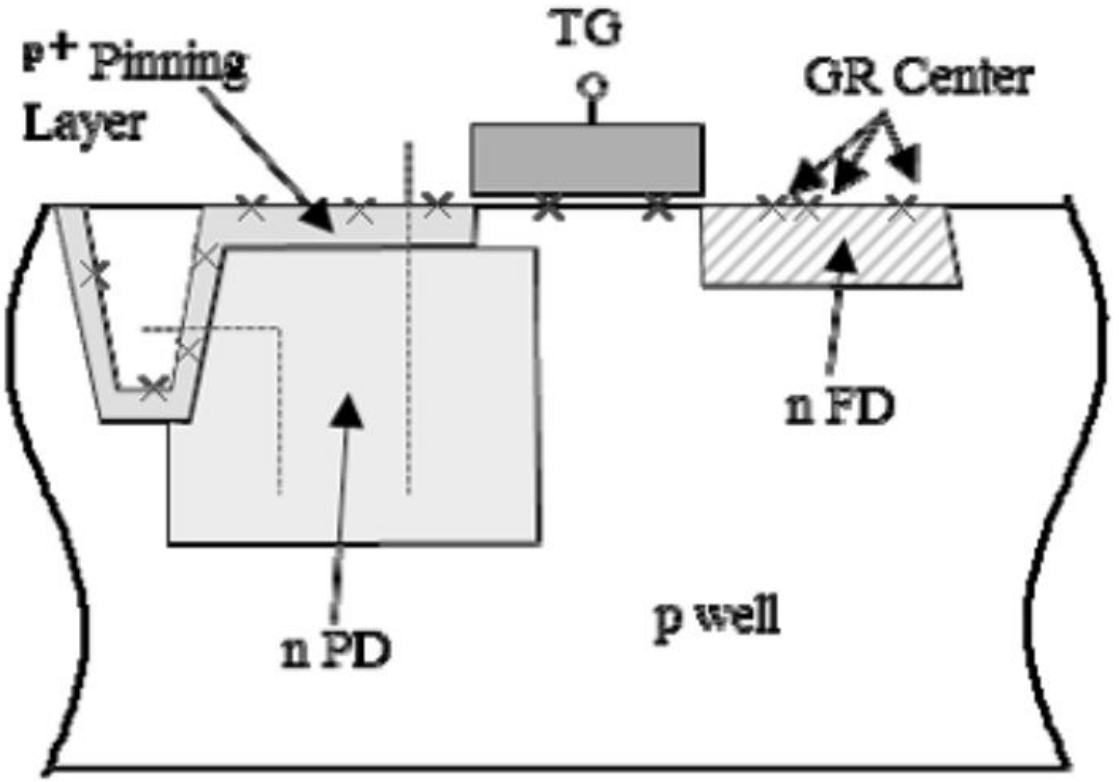



Figure 1: Structure of a CMOS active pixel [5].

Understanding Noise and Noise Reduction in CMOS Imaging Sensors (arxiv, 24)

# Photodiode



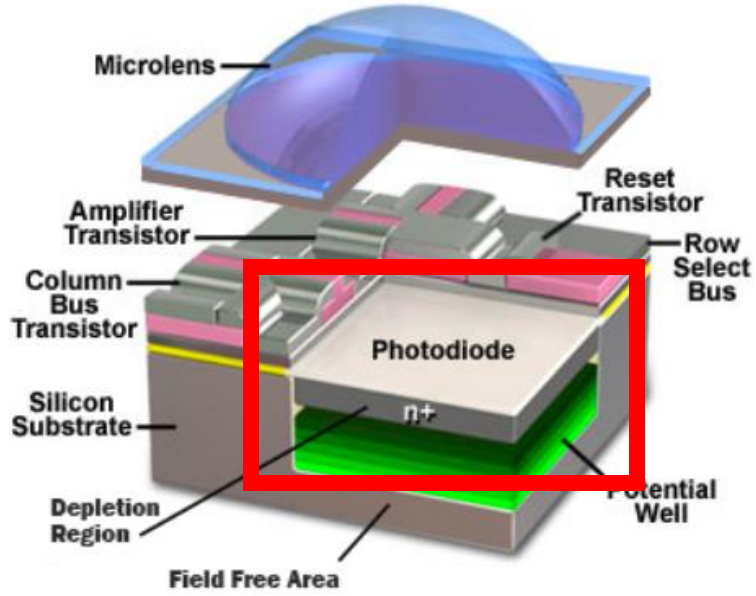
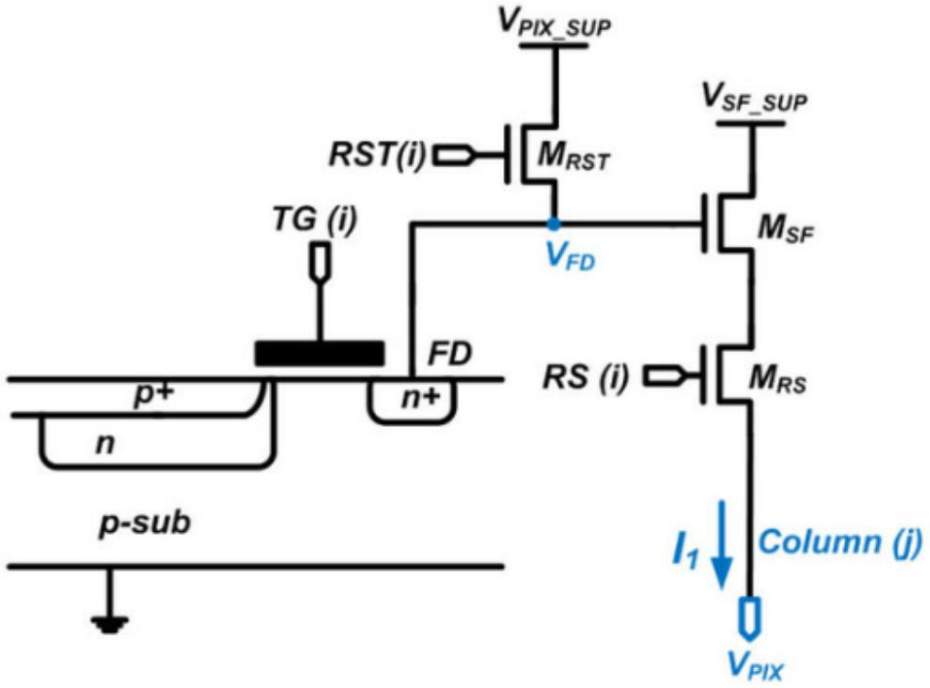



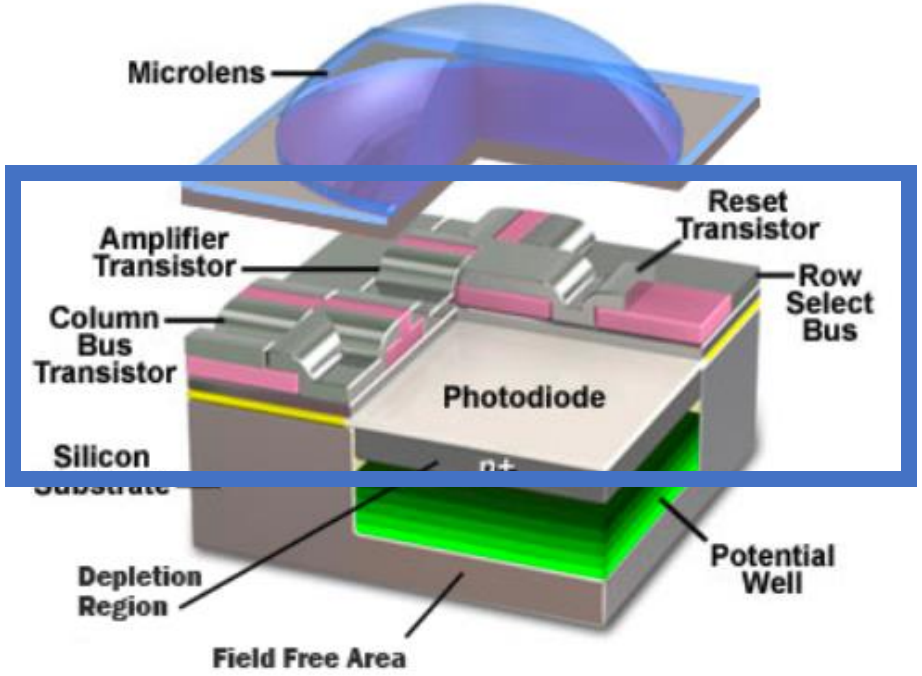

Figure 1: Structure of a CMOS active pixel [5].

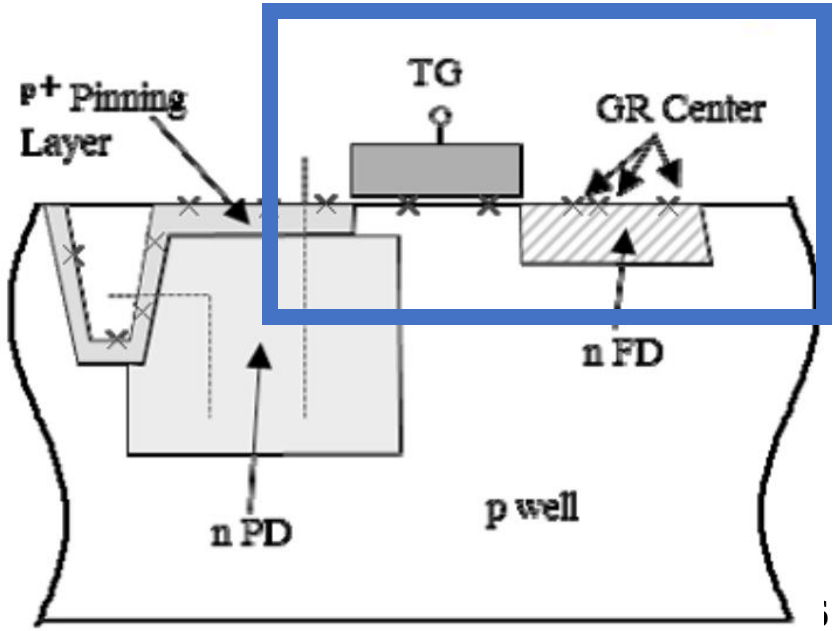
⚡ **光電子移動的順序**

- 光打在 nPD 上，光電效應產生光電子
- 接著因為 p+ Pinning Layer 的電場，克服 nPD 與 p well 之間的 depletion region 使電子加速移動到 p Well (Potential Well) 裡儲存
- 接著因為 TG (Transfer Gate) 給的電壓，使 p Well 與 nFD (Floating Diffusion) 連通，讓電子最後存在 nFD
- nFD 電壓改變，等待 Sense Node 來 read out 這個電壓，成為 working voltage。

# 4T transistor design

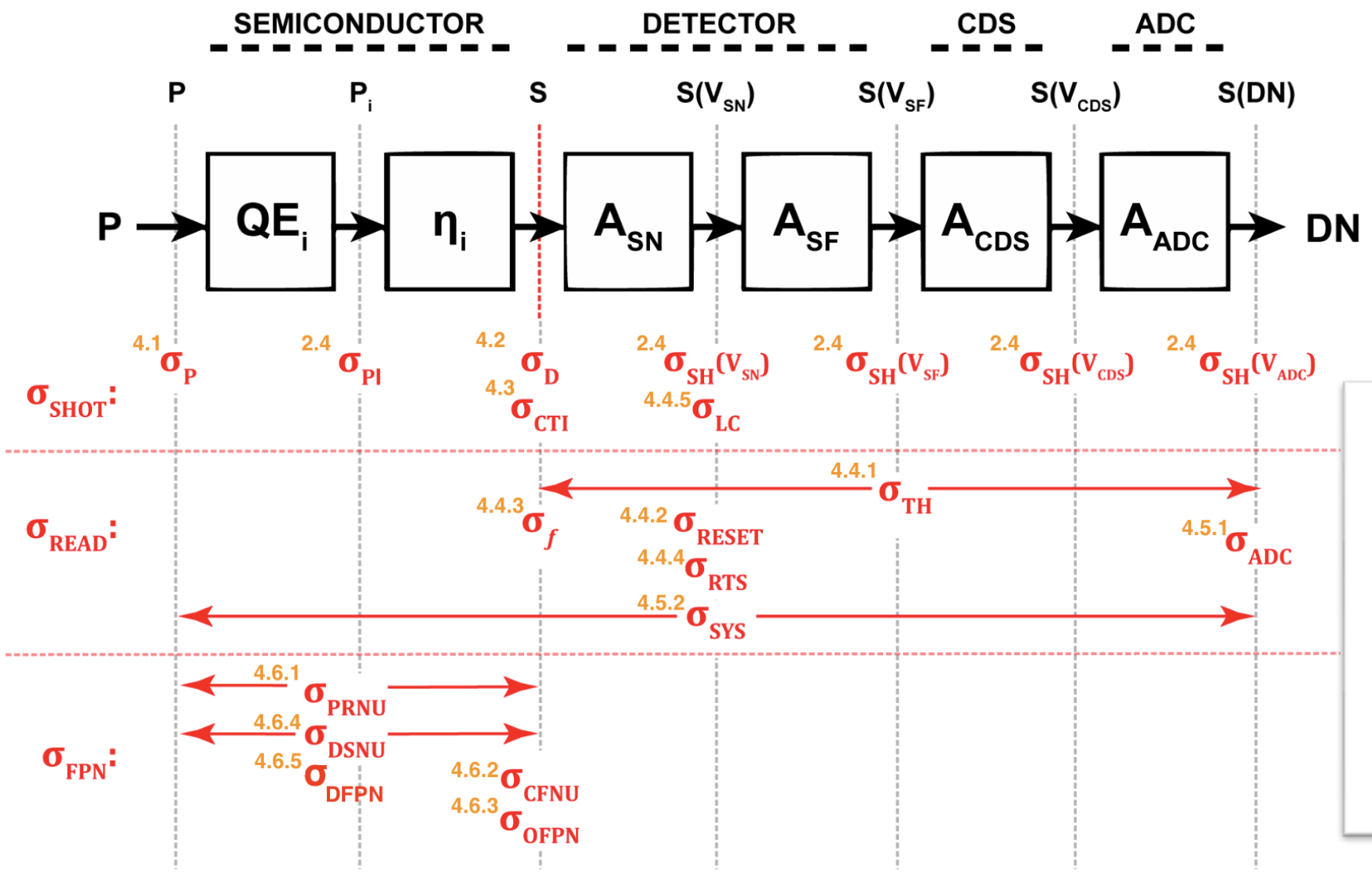


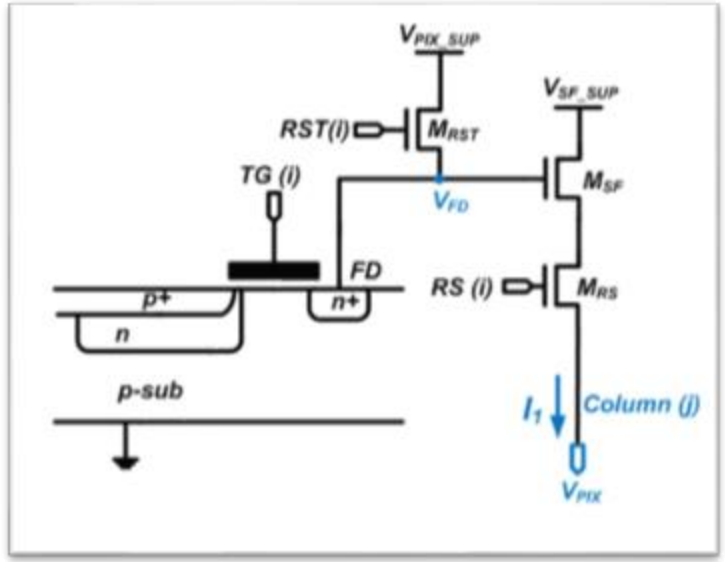



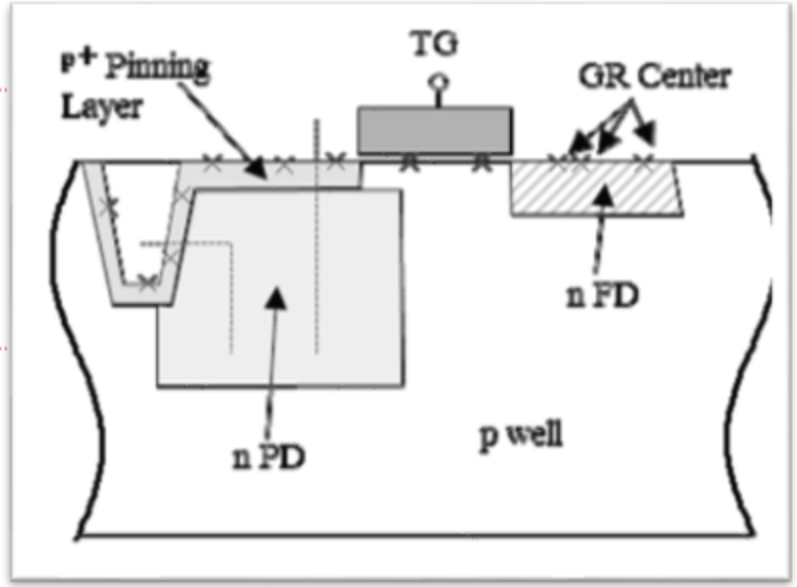




- Transfer gate and transfer transister (TG)
- Source follower transistor (amplifier)
- Row select transistor (MRS)
- Reset transistor (MRST)

# Noise overview



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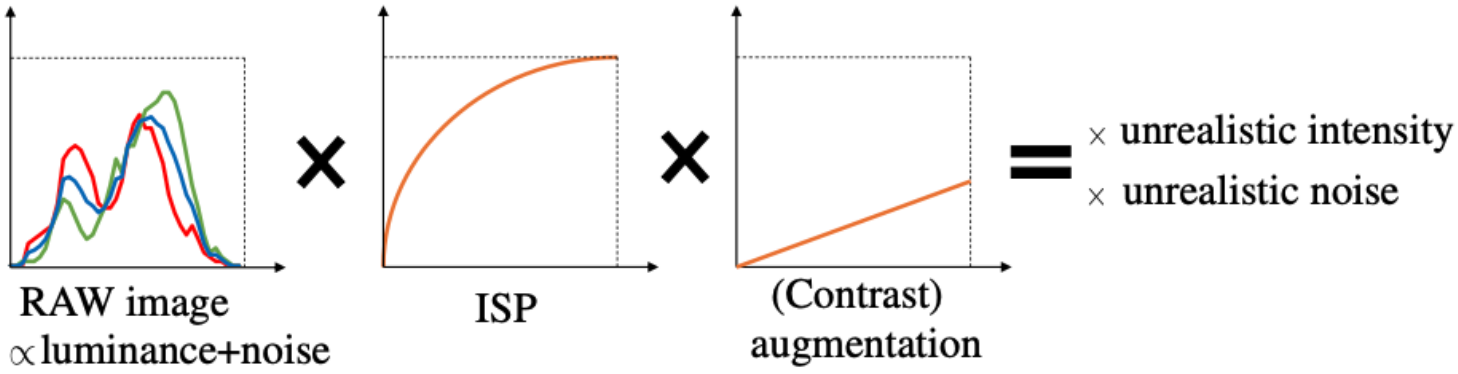
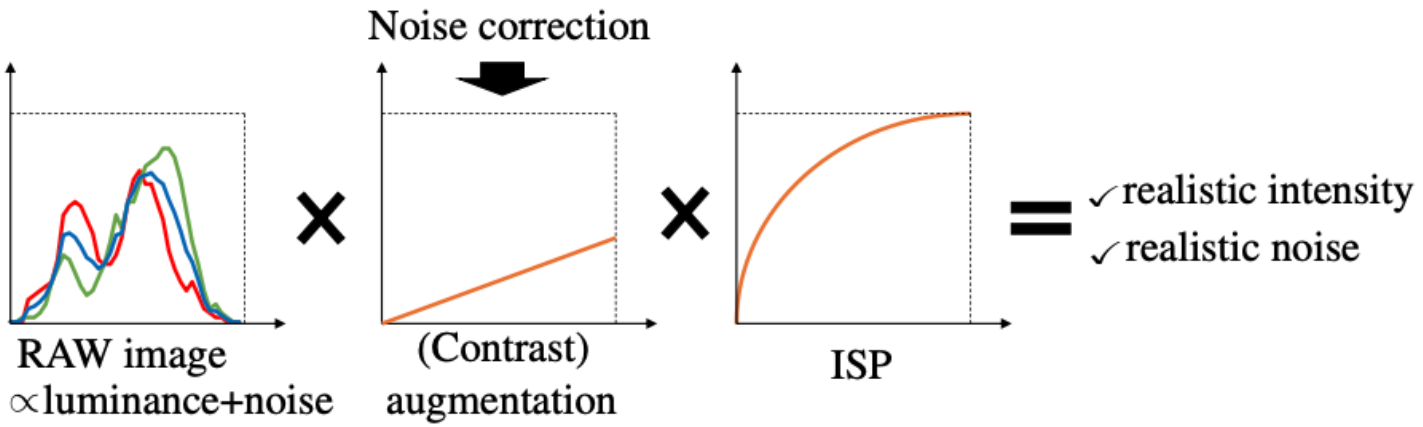
# Introduction




(a) Usual training pipeline




(b) Noise-accounted RAW augmentation pipeline

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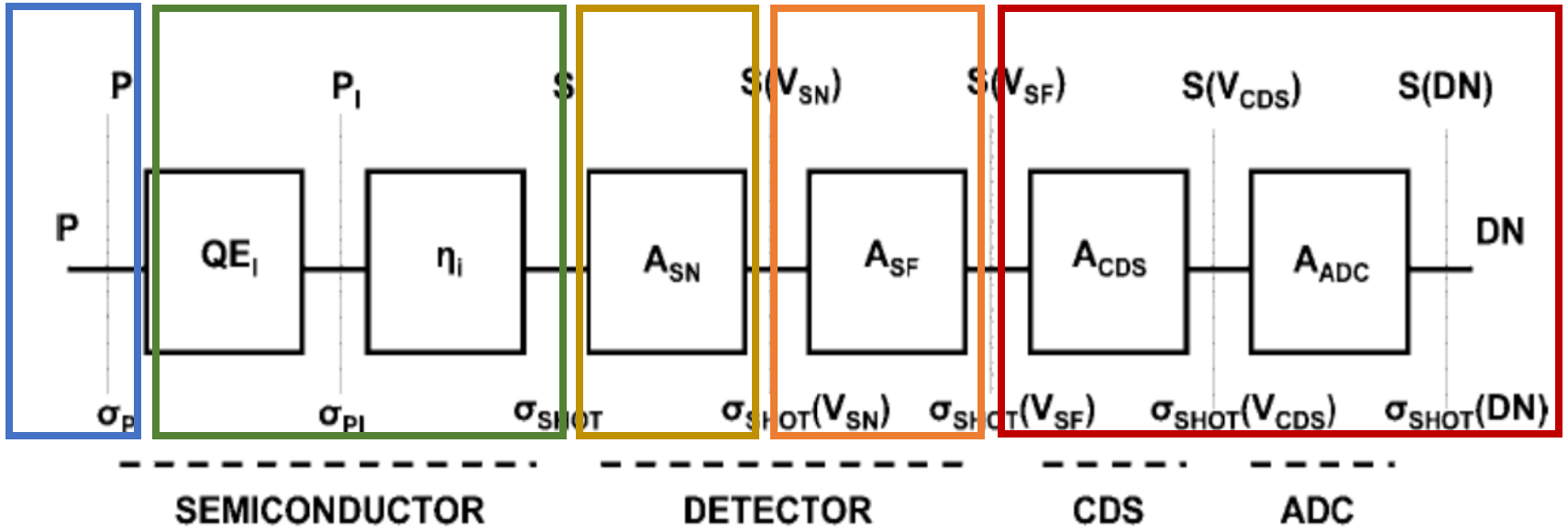
# Noise modeling




$$x = g\left(\alpha u + n_d\right) + n_r.$$

$$x \sim g\left(\alpha \mathcal{N}\left(\bar{u}, \bar{u}\right) + \mathcal{N}\left(0, \sigma_d^2\right)\right) + \mathcal{N}\left(0, \sigma_r^2\right).$$

# Noise modeling

$$x \sim g\left(\alpha\mathcal{N}\left(\bar{u},\bar{u}\right)+\mathcal{N}\left(0,\sigma_d^2\right)\right)+\mathcal{N}\left(0,\sigma_r^2\right).$$

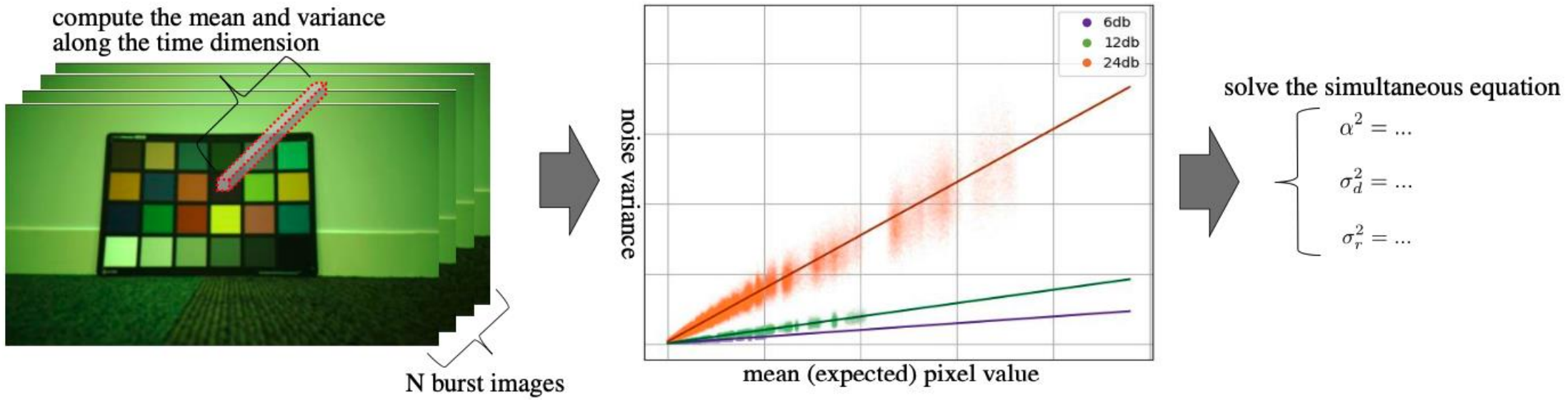
$$\begin{cases} X \sim \mathcal{N}\left(\mu_X,\sigma_X^2\right) \\ Y \sim \mathcal{N}\left(\mu_Y,\sigma_Y^2\right) \\ X+Y \sim \mathcal{N}\left(\mu_X+\mu_Y,\sigma_X^2+\sigma_Y^2\right) \\ cX \sim \mathcal{N}\left(c\mu_X,c^2\sigma_X^2\right) \end{cases},$$

$$x \sim \mathcal{N}\left(g\alpha\bar{u},g^2\alpha^2\bar{u}+g^2\sigma_d^2+\sigma_r^2\right).$$

$$x \sim \mathcal{N}\left(\mu_x,\sigma_x^2=g\alpha\mu_x+g^2\sigma_d^2+\sigma_r^2\right).$$

# Noise Model Calibration

$$x \sim \mathcal{N}\left(\mu_x, \sigma_x^2 = g\alpha\mu_x + g^2\sigma_d^2 + \sigma_r^2\right).$$



# Noise-Accounted RAW Augmentation

$$x \sim \mathcal{N}\left(g\alpha\bar{u}, g^2\alpha^2\bar{u} + g^2\sigma_d^2 + \sigma_r^2\right).$$

$$x \sim \mathcal{N}\left(\mu_x, \sigma_x^2 = g\alpha\mu_x + g^2\sigma_d^2 + \sigma_r^2\right).$$

$$x_{new} \sim \mathcal{N}\left((p_g g)\alpha(p_u\bar{u}), (p_g g)^2\alpha^2(p_u\bar{u}) + (p_g g)^2\sigma_d^2 + \sigma_r^2\right).$$

# Noise-Accounted RAW Augmentation

$$x_{new} \sim \mathcal{N}\left( \begin{matrix} (p_g g)\alpha(p_u \bar{u}), \\ (p_g g)^2 \alpha^2 (p_u \bar{u}) + (p_g g)^2 \sigma_d^2 + \sigma_r^2 \end{matrix} \right).$$

$$x_{new} \sim p_u p_g x_{pre} +$$

$$\mathcal{N}(0,\ p_u(1-p_u)p_g^2 g\alpha\mu_x + (1-p_u^2)p_g^2 g^2\sigma_d^2 + (1-p_u^2 p_g^2)\sigma_r^2). \quad (11)$$

# Noise-Accounted Blur Augmentation

$$x \sim \mathcal{N}\left(g\alpha\bar{u}, g^2\alpha^2\bar{u} + g^2\sigma_d^2 + \sigma_r^2\right).$$

$$x \sim \mathcal{N}\left(\mu_x, \sigma_x^2 = g\alpha\mu_x + g^2\sigma_d^2 + \sigma_r^2\right).$$

$$x_{new} \sim \mathcal{N}\left(g\alpha\sum_k w_k\bar{u}_k,\ g^2\alpha^2\sum_k w_k\bar{u}_k + g^2\sigma_d^2 + \sigma_r^2\right), \tag{14}$$

# Noise-Accounted Blur Augmentation

$$x_{new} \sim \mathcal{N}\left(g\alpha \sum_k w_k \bar{u}_k,\ g^2\alpha^2 \sum_k w_k \bar{u}_k + g^2\sigma_d^2 + \sigma_r^2\right), \tag{14}$$

$$\sum_k w_k x_{pre} + \mathcal{N}\left(0,\ g\alpha \sum_k (1 - w_k) w_k x_{pre,k} + (1 - \sum_k w_k^2)(g^2\sigma_d^2 + \sigma_r^2)\right).$$

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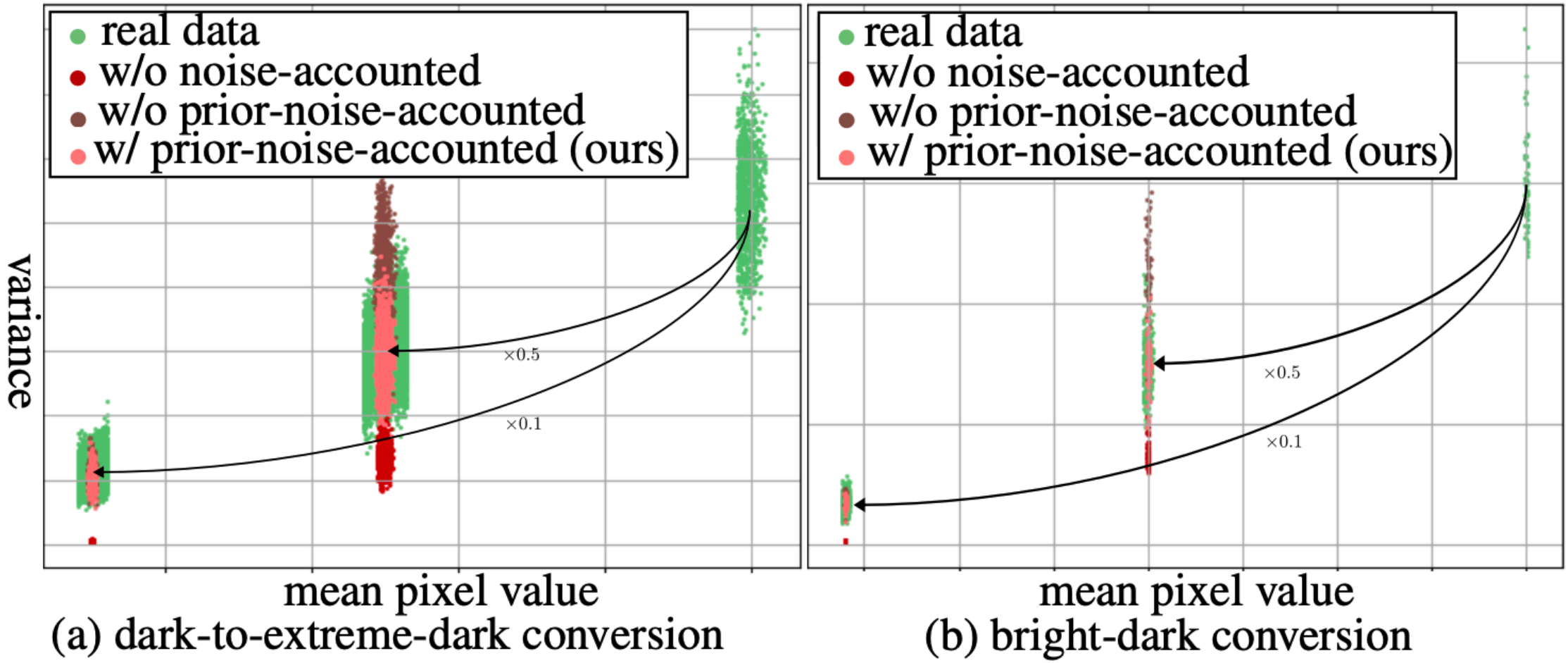
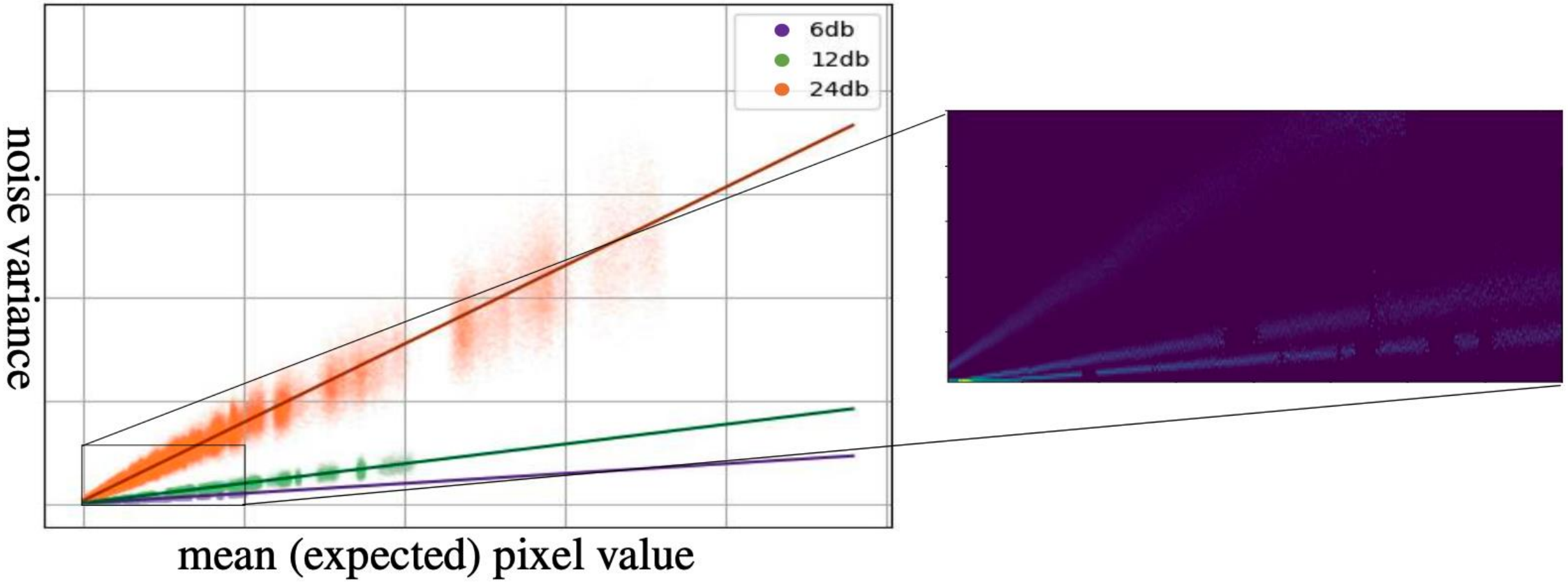
# Dataset

# Results


real data
w/o noise-accounted
w/o prior-noise-accounted
w/ prior-noise-accounted (ours)
variance
×0.5
×0.1
mean pixel value
(a) dark-to-extreme-dark conversion
real data
w/o noise-accounted
w/o prior-noise-accounted
w/ prior-noise-accounted (ours)
×0.5
×0.1
mean pixel value
(b) bright-dark conversion

# Results




coefficients of determination, $R^2$, for these line estimations are 0.9833, 0.9884, 0.9862 for 6, 12, and 24dB respectively

# Results

| method | AP@0.5:0.95 [%] w/o ISP | AP@0.5:0.95 [%] w/ ISP |
|---|---|---|
| concat [2] | 16.5 | 21.5 |
| aug. + concat [2] | **35.0** | 31.6 |
| our aug. + concat [2] | 33.7 | 40.4 |
| K-Sigma [44] | 14.3 | 27.5 |
| K-Sigma [44] + aug. | 25.0 | 34.1 |
| aug. + K-Sigma [44] | 26.6 | 42.1 |
| our aug. + K-Sigma [44] | 26.3 | 44.0 |
| our aug. | 32.8 | **45.3** |

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# Conclusion

- Propose a noise-accounted RAW augmentation method

- Unlike previous noise-accounted methods, ours takes the prior input noise into account.