

# Willems' fundamental lemma based on second-order moments

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$$\begin{array}{c}
 \begin{bmatrix} u_{ini} \\ u \\ \mathbf{y} \end{bmatrix} = \begin{bmatrix} U_p \\ U_f \\ Y_p \\ Y_f \end{bmatrix} g = \begin{bmatrix} u_0^d & u_1^d & \cdots & u_{M-1}^d \\ \vdots & \vdots & \ddots & \vdots \\ u_{L-1}^d & u_L^d & \cdots & u_{T-1}^d \\ y_0^d & y_1^d & \cdots & y_{M-1}^d \\ \vdots & \vdots & \ddots & \vdots \\ y_{L-1}^d & y_L^d & \cdots & y_{T-1}^d \end{bmatrix} g \\
 \begin{array}{l} \nearrow \\ \text{online noise} \end{array} \\
 \begin{array}{l} \nearrow \\ \text{offline noise} \end{array}
 \end{array}$$

We propose variations to minimize offline noise in data using:

- correlation functions in the time domain,
- power spectra in the frequency domain.