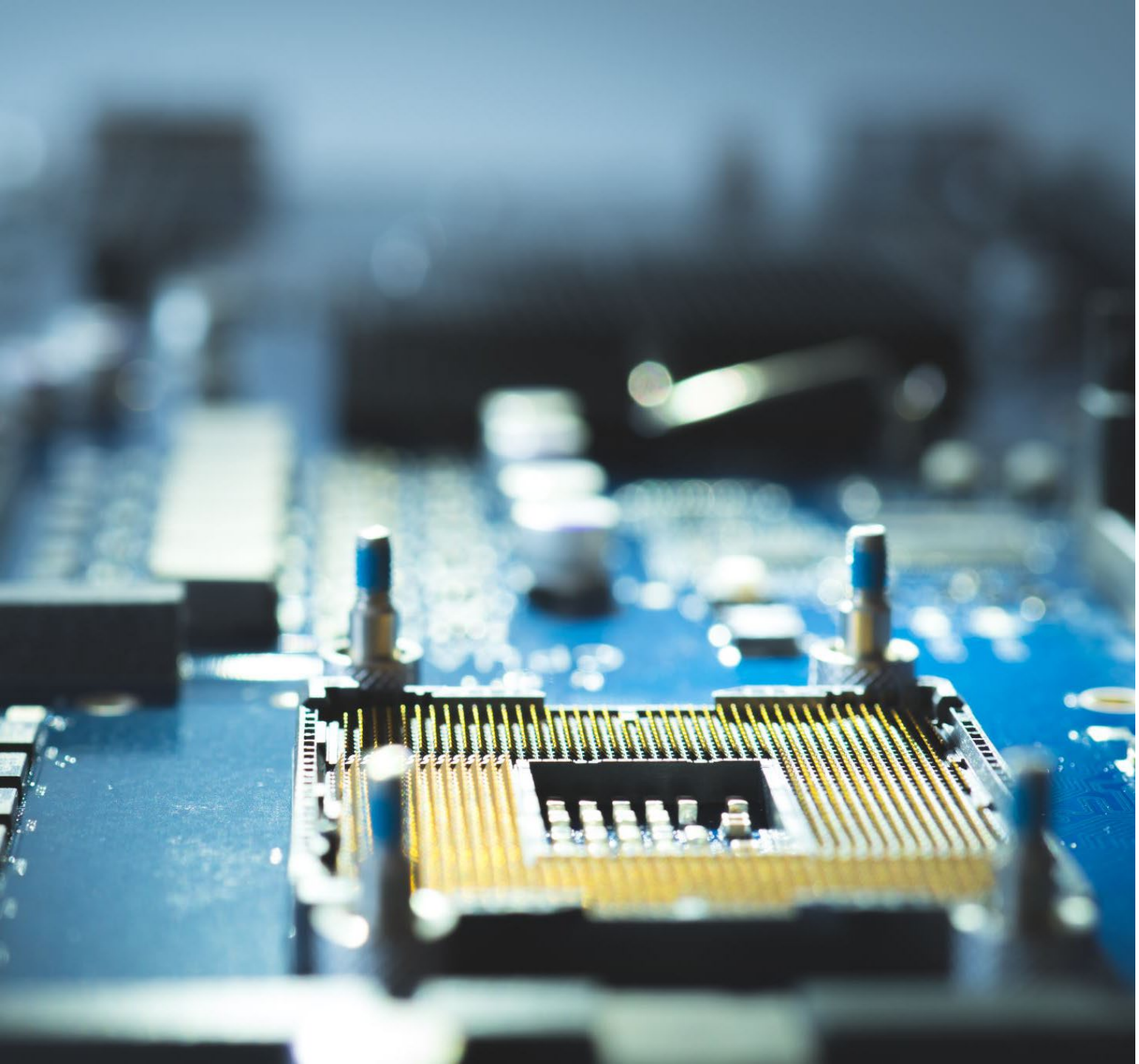


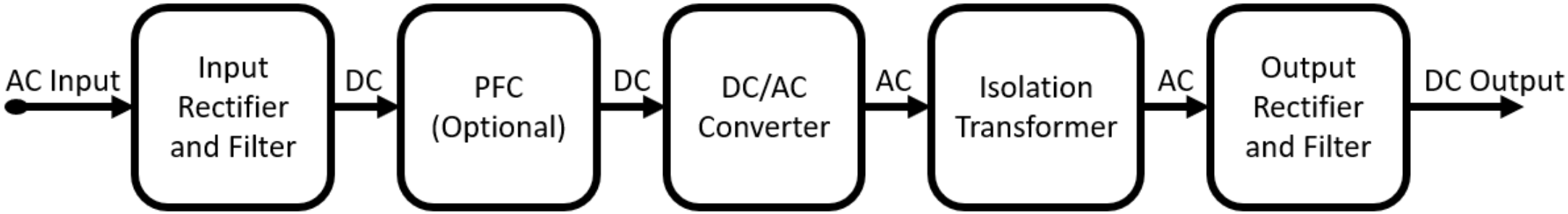
By Ahmad Faza

19 November 2021

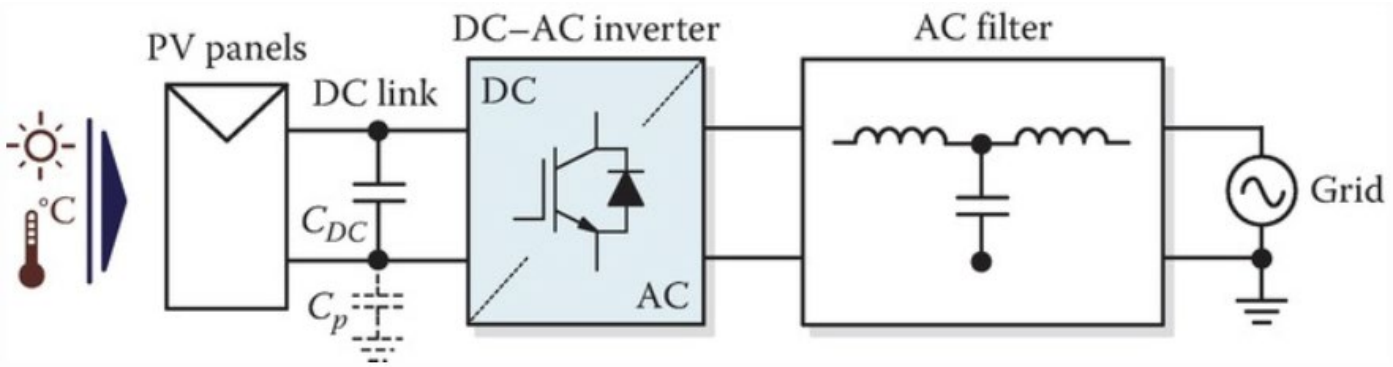
ADVANCED DITHERING TECHNIQUES FOR POWER ELECTRONICS AND CONTROL

ELECTRIC POWER CONVERSION

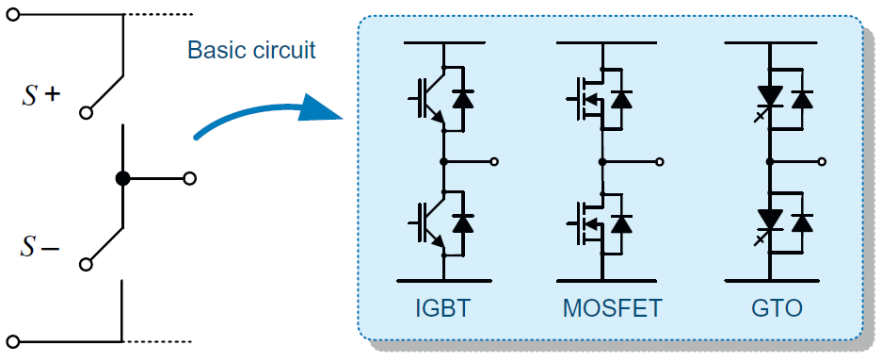
- Switched-Mode AC/DC Power Supply [1]

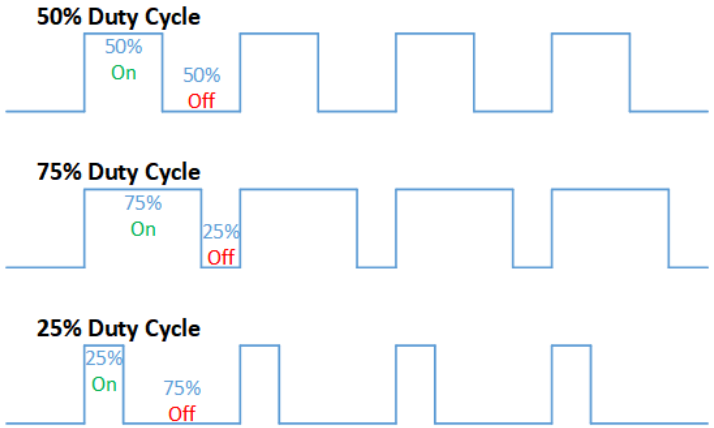


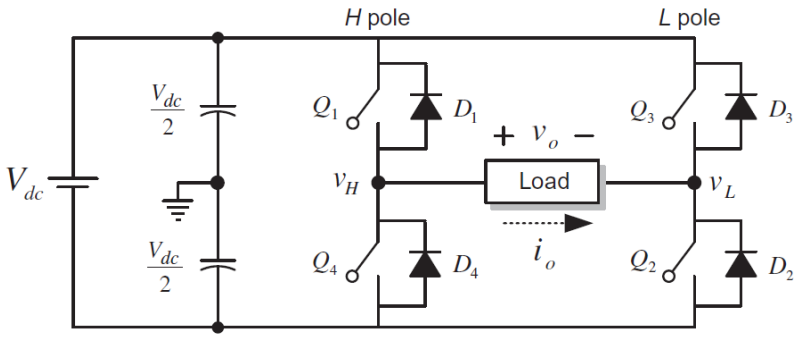
- DC/AC Power Converter [2]

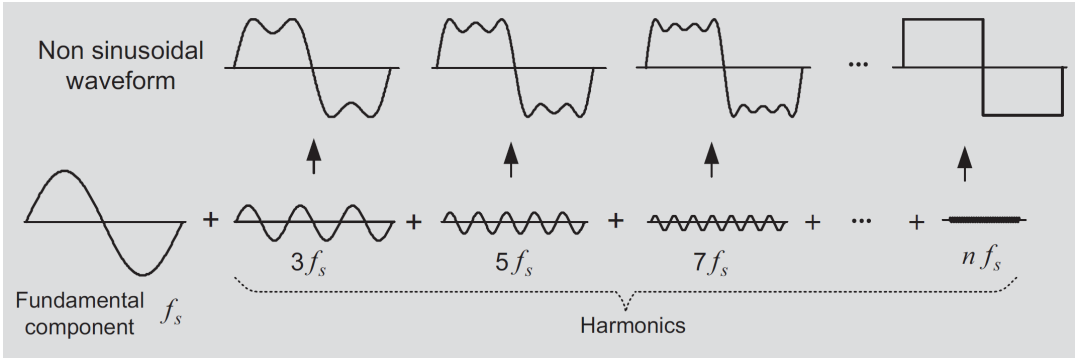


POWER CONVERTERS COMPONENTS & PWM [3]



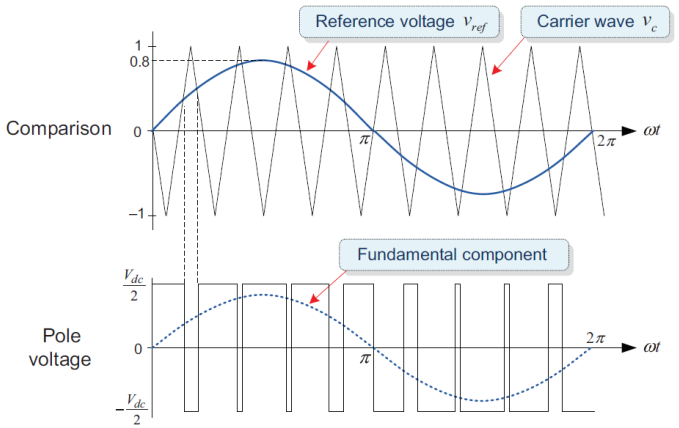




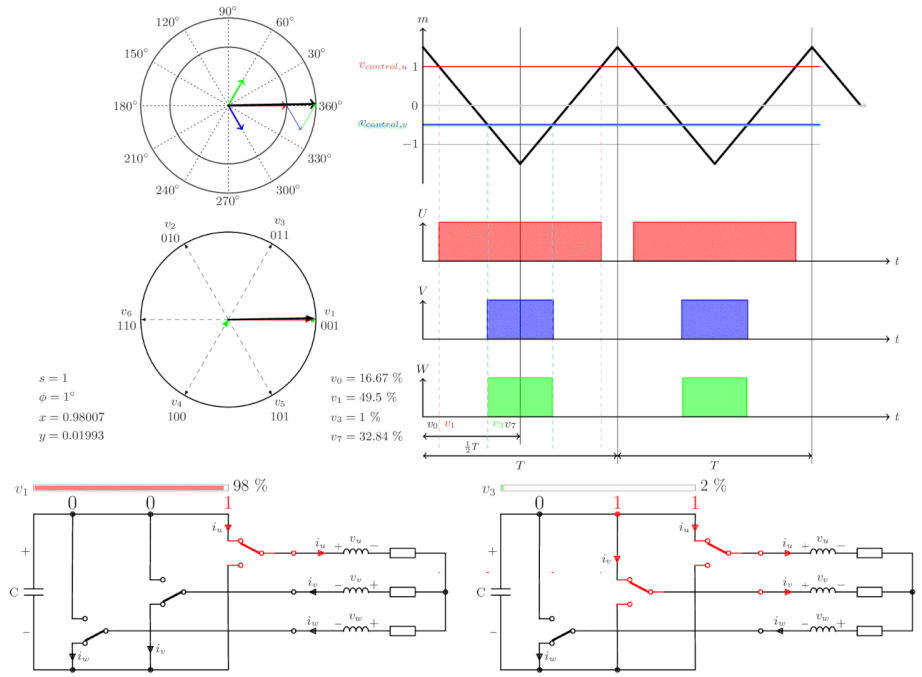


CONVENTIONAL CONTROL

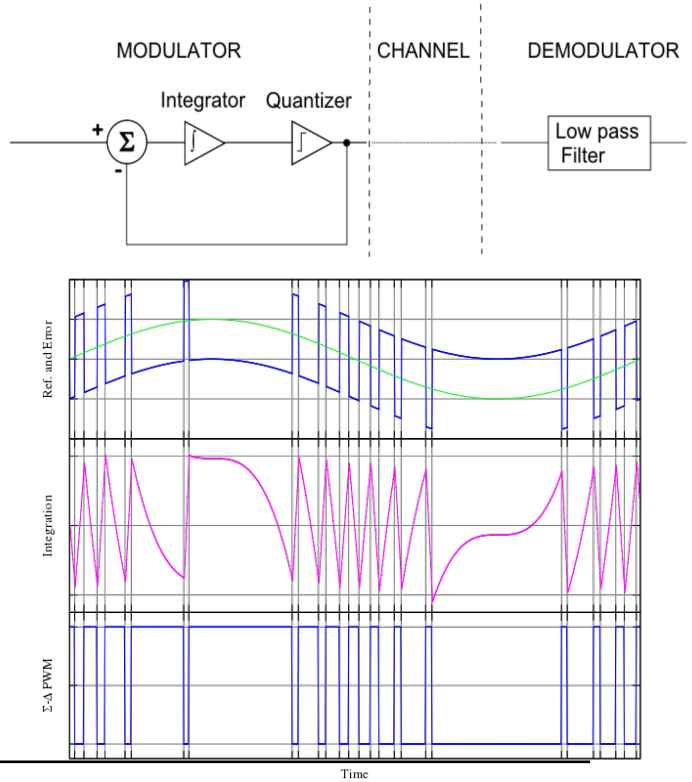
- SPWM [3]



- SVPWM [4]

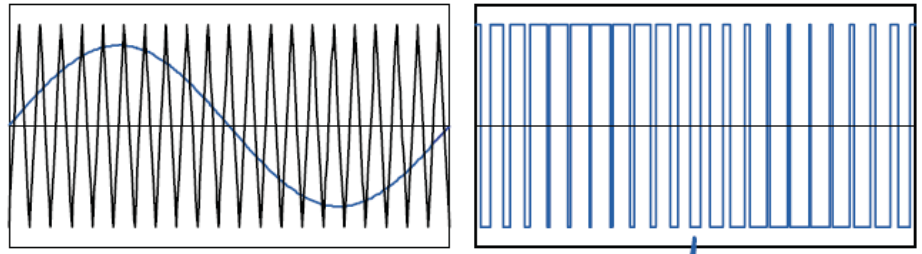


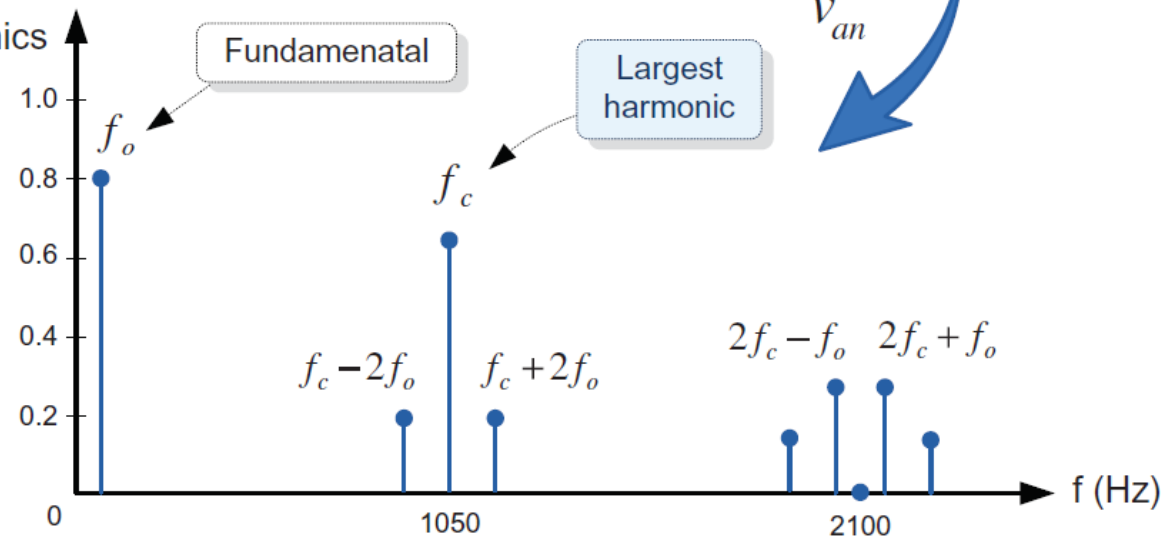
- Δ-$\sum$ Modulation [5]



FREQUENCY RESPONSE [3]

- EMI
- THD





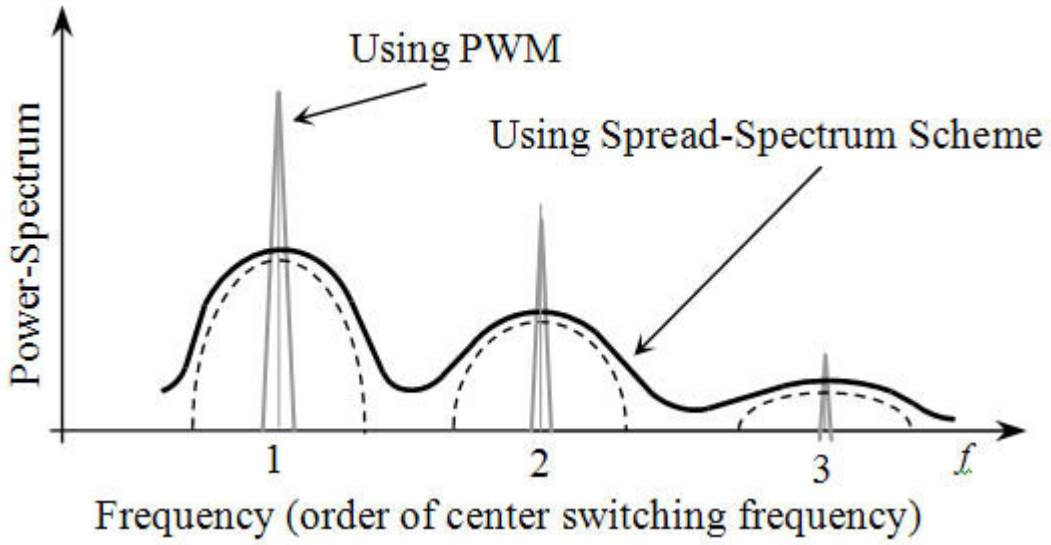
$$THD_F = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 \ldots}}{V_1}$$

THD = total harmonic distortion

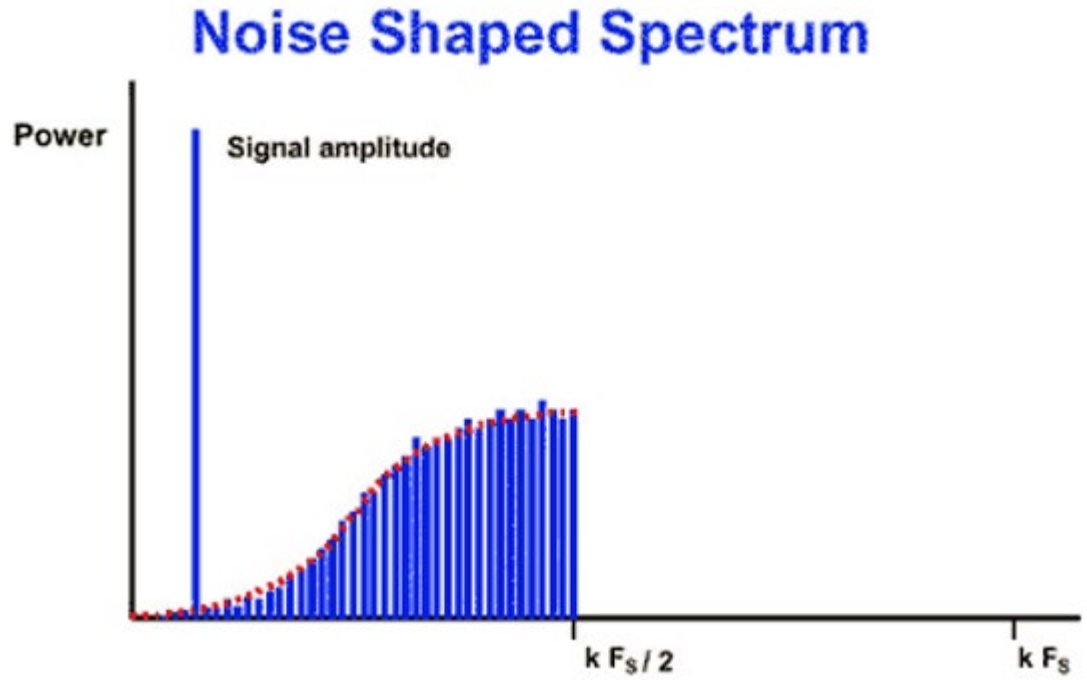
V_n = RMS voltage of the nth harmonic

CONTROL DESIGN GOALS

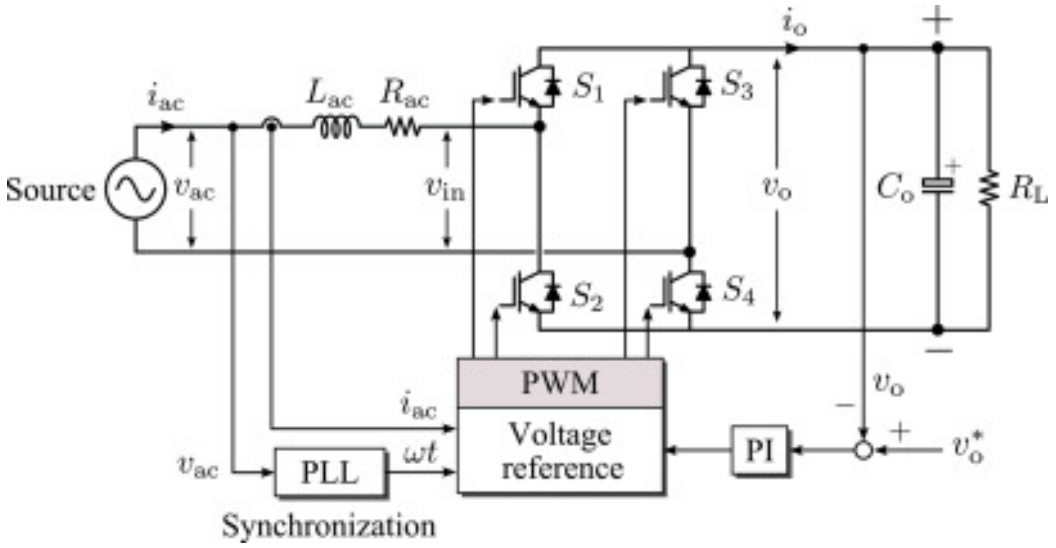
- Spreading power conversion harmonic content artifacts [4]

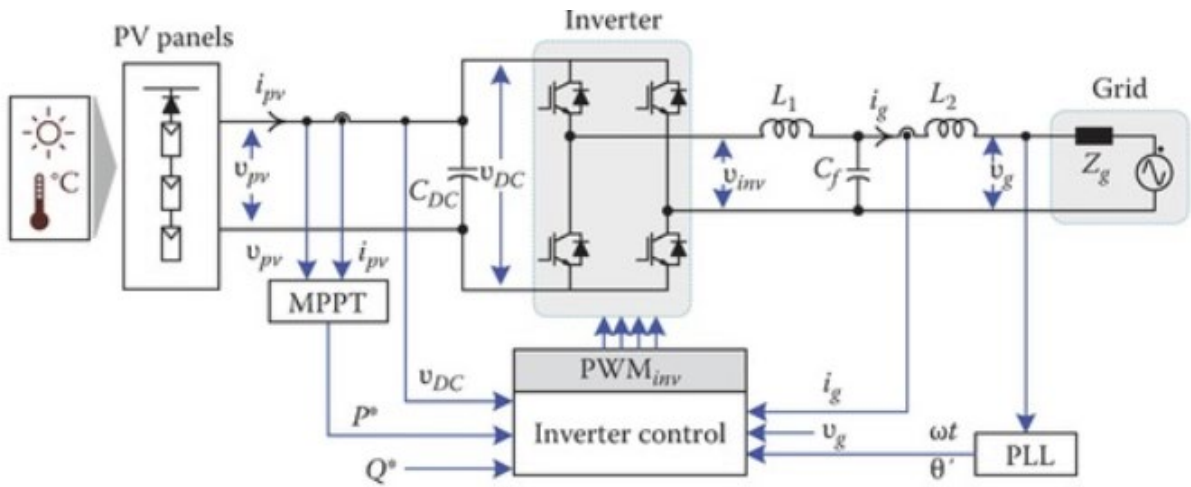


- Noise Shaping



POWER ELECTRONIC CONVERTERS





- Single Phase AC/DC Converters [1]
- Single Phase DC/AC Converters [2]

MODEL PREDICTIVE CONTROL (MPC) [6]

$$\min_{\Delta\mathcal{U}(k)} V(k) = \sum_{i=H_w}^{H_p} \|\hat{z}(k+i|k) - r(k+i|k)\|^2_{Q(i)} + \sum_{i=0}^{H_u-1} \|\Delta\hat{u}(k+i|k)\|^2_{R(i)}$$

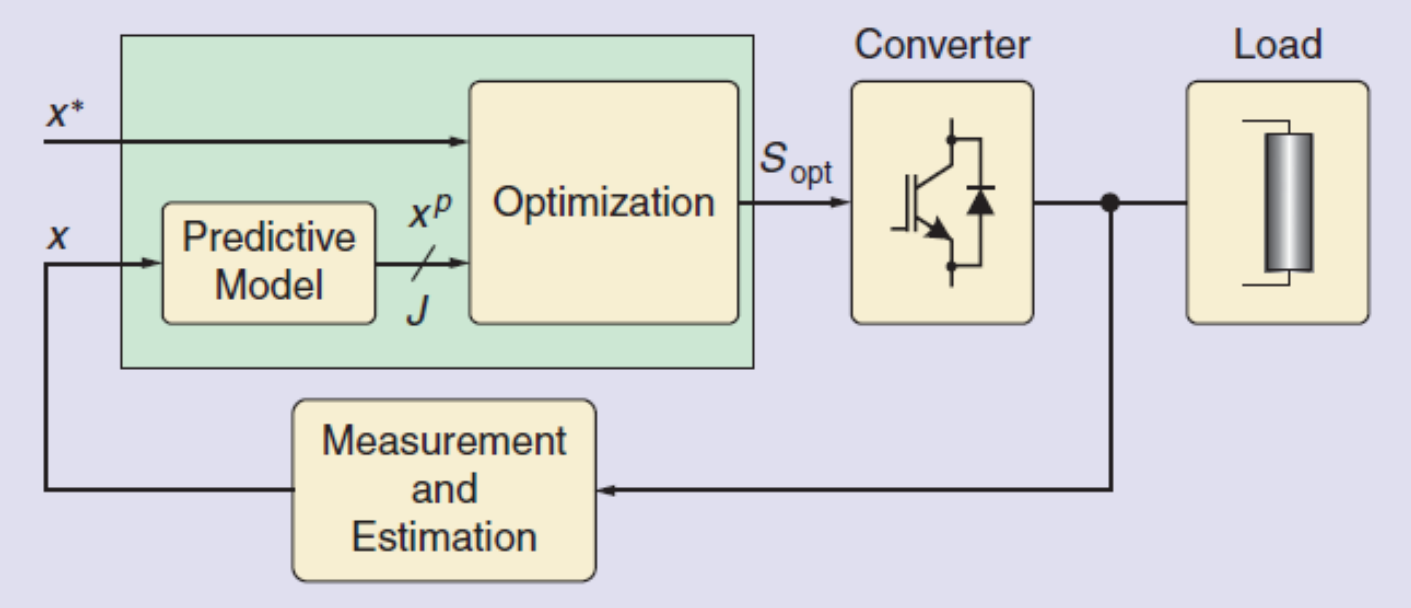
$\|w\|_M = \sqrt{w^T M w}$

weights: $Q(i), R(i) \geq 0$

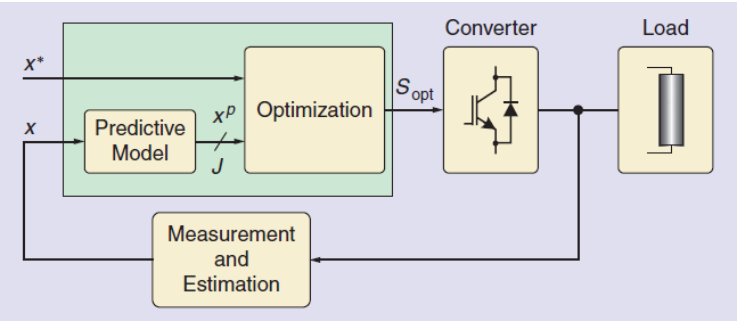
reference signal $r(k+i|k)$

prediction horizon $H_p \geq$ co

window parameter $H_w \geq 1$



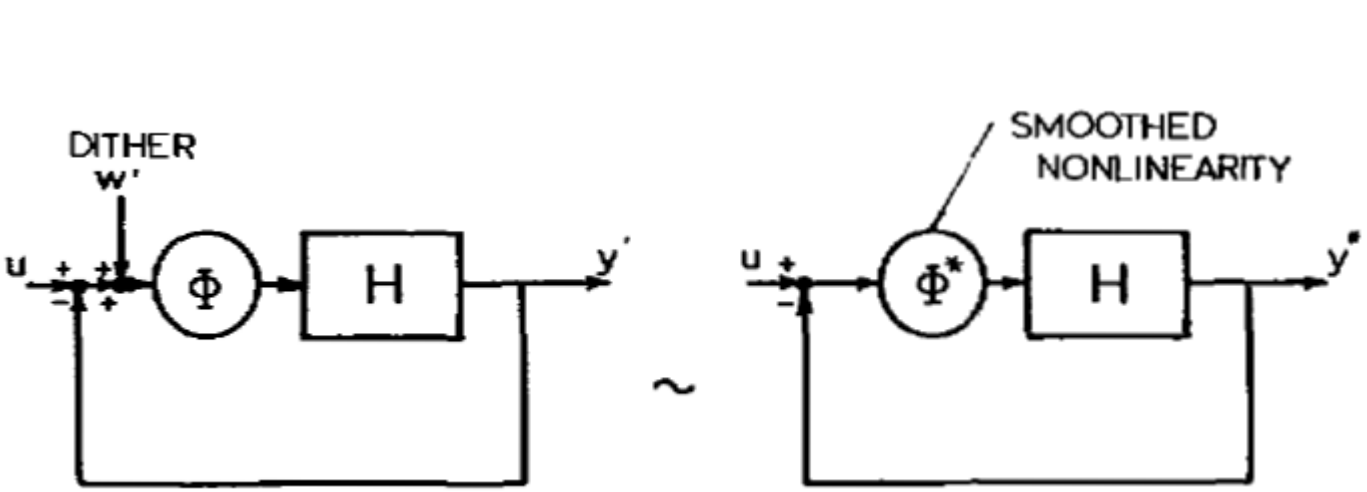
MPC [6]

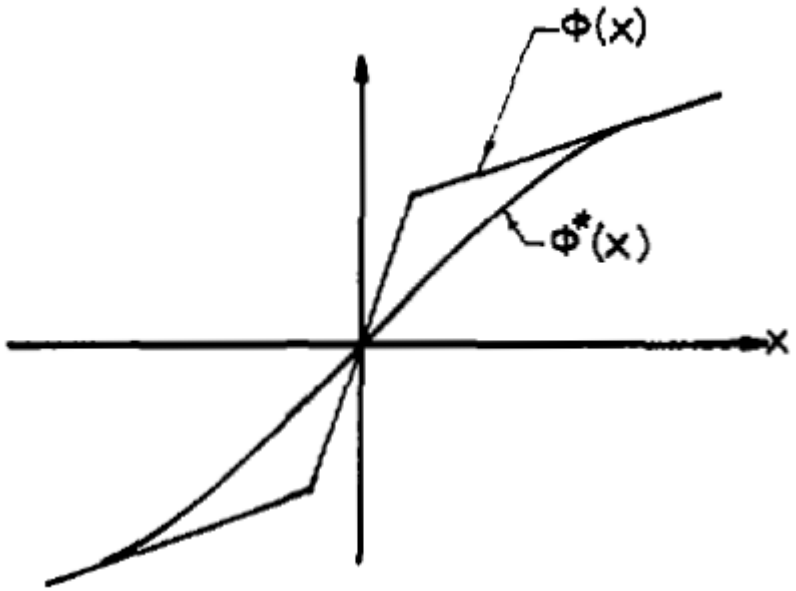


- High computational burden
- Slow Processes

WHAT IS DITHERING?

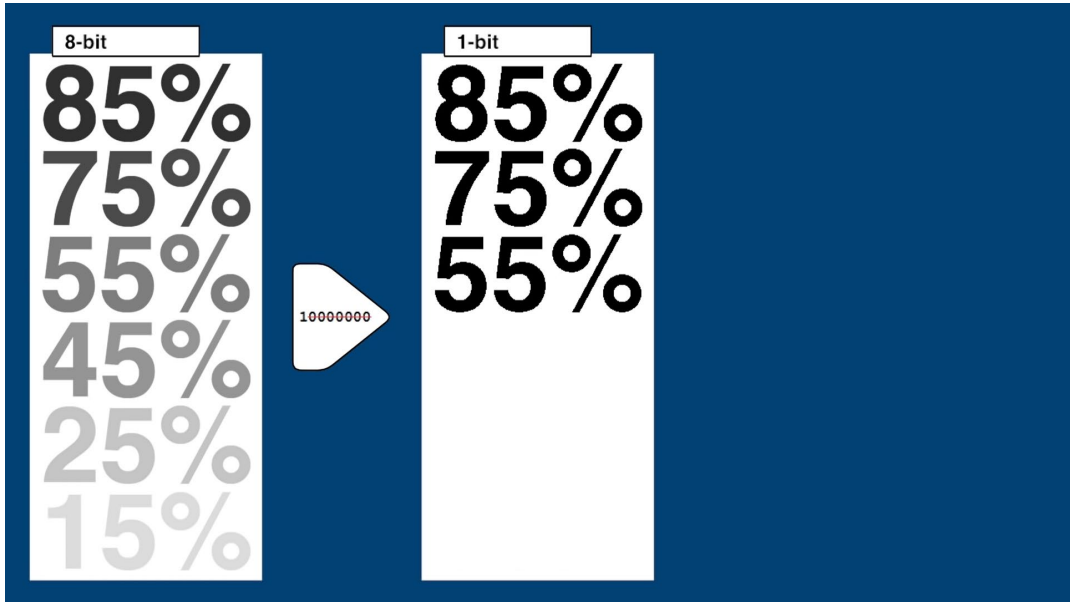
- Dithering: is a process by which a form of noise is intentionally applied to a signal to randomize the quantization error (e.g. due to intended resolution reduction) [3].



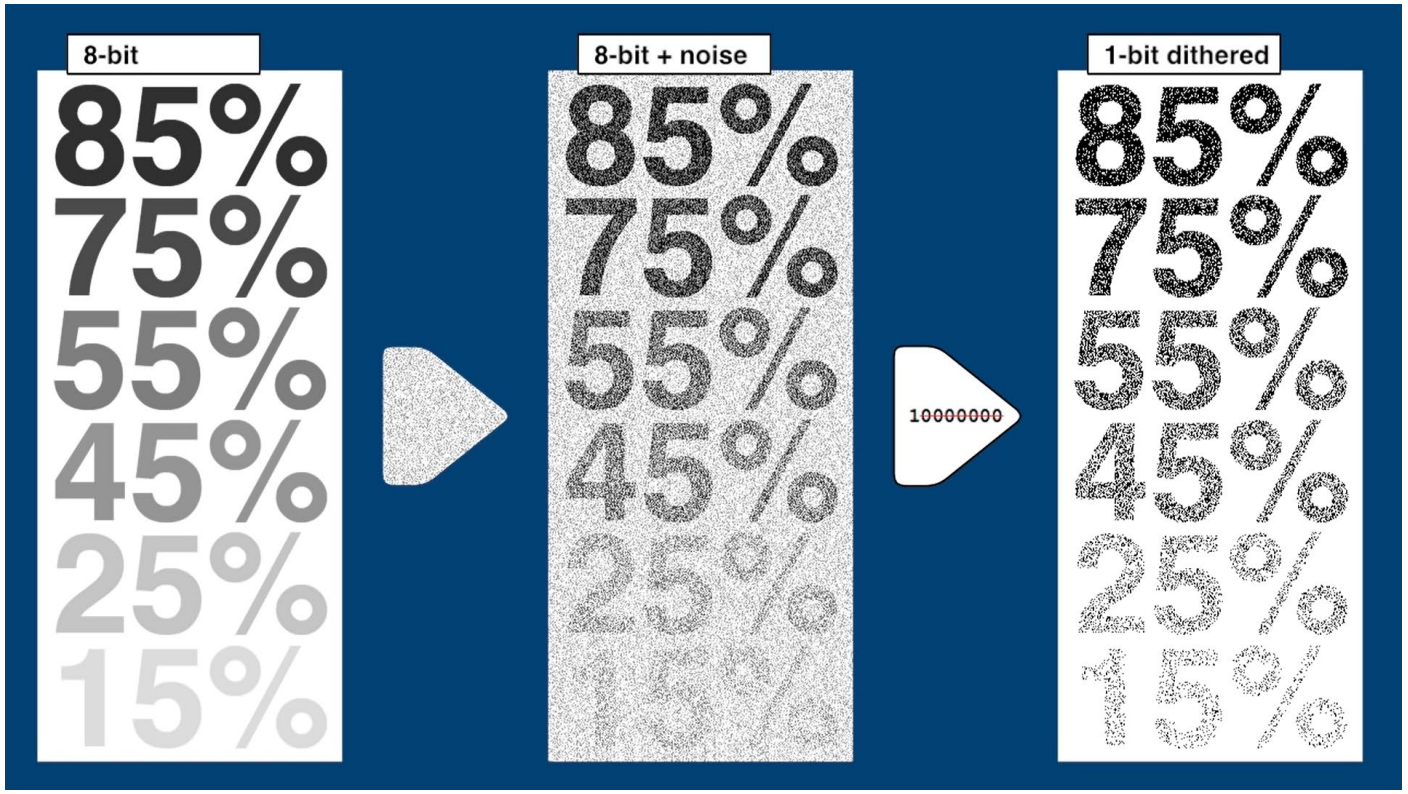


DITHERING EXAMPLE

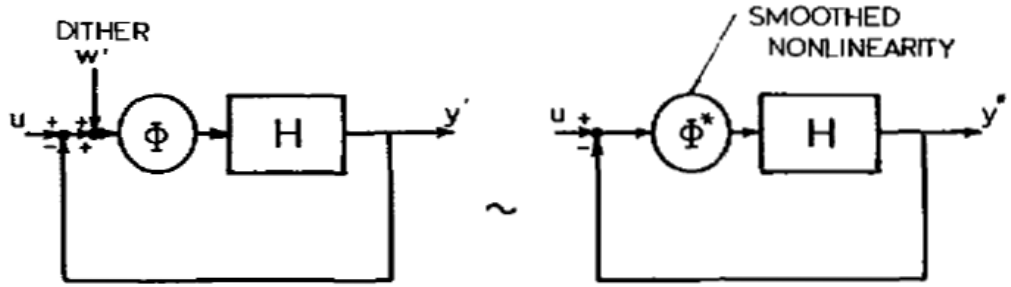
Ideal Quantization

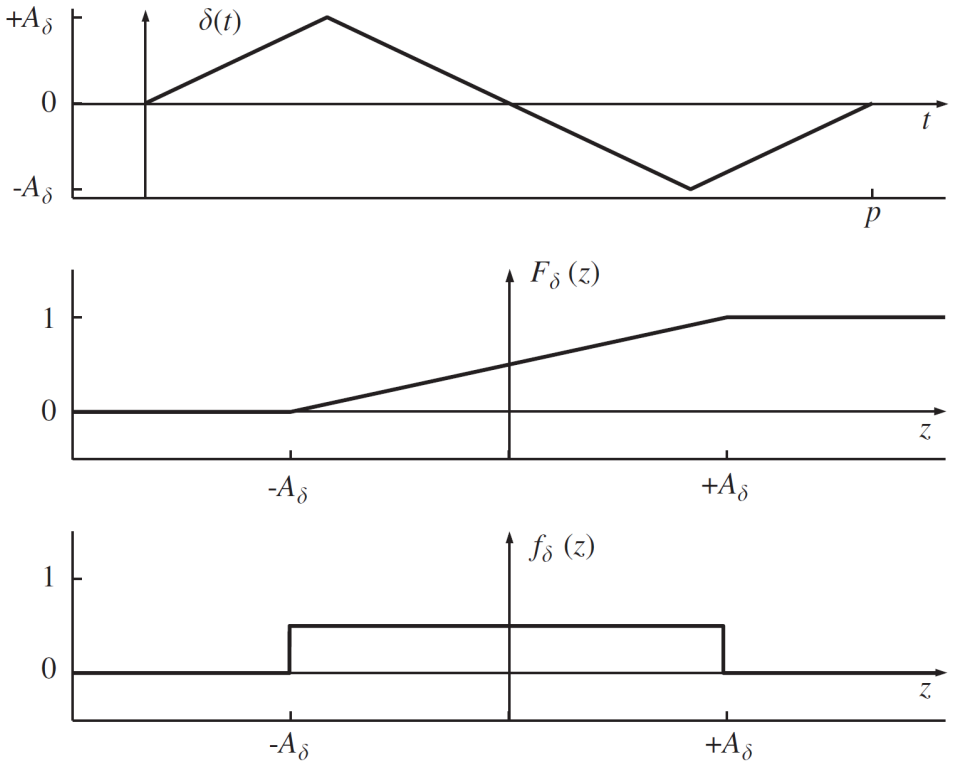


Dithered system



DITHER CHARACTERISTICS

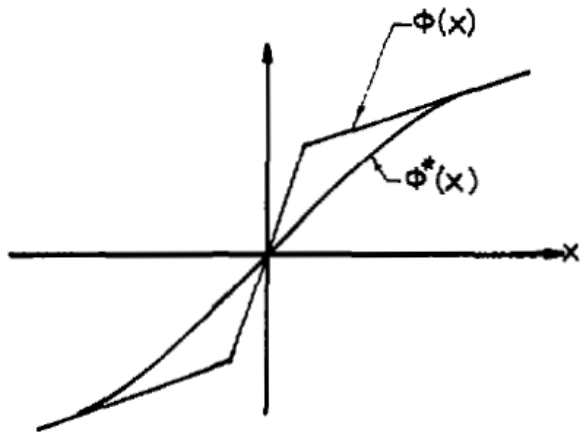




$$N(z) \triangleq \int_{\mathbb{R}} n(z+\xi)\,\mathrm{d}F_\delta(\xi)$$

$$= \frac{1}{p}\int_{[0,p)} n(z+\delta(s))\,\mathrm{d}s$$

$$= \int_{\mathbb{R}} n(z+\xi)\,f_\delta(\xi)\,\mathrm{d}\xi$$



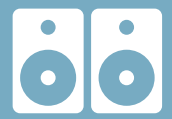
RESEARCH QUESTIONS

- *How can **improved modelling** of switched-mode devices enhance the performance in existing control schemes as well as predicting the performance when applying dithering.*
- *How can signals, suitable for dithering, be **generated** when there are simultaneous specifications for the value/**probability** and frequency/**spectral** distribution.*
- *When designing improved dither signals, it is of interest to investigate the properties of applying such signals in **closed loop**.*
- *What **potential applications** in the broad variety of switched-mode non-linear power converters control would dithering techniques prove to be **most useful**, feasible to implement and hold **a competitive edge** over other predominant and/or emergent control techniques.*

INNOVATION IN RESEARCH

- The attempt to utilize well-proven dithering techniques characteristics in the field of power conversion applications is **novel**.
- Recognizing the quantization effect out of the usual context of digital to analog conversion to optimize simplistic control methods such as **PID**, **PWM**.
- The approach opens the door to target **noise spectrum spreading** as an inherent feature that can be used in forming the optimization problem.
- Allows for a viable trade-off for computationally intensive state of the art methods such as Model Predictive Control (**MPC**).

COMMERCIAL IMPACT



Can be easily retrofit into currently available topologies (add a "**noise**" with special properties) at as low costs as adding a prerecorded storage unit for an application specific noise.

Drastically reduce inherent radiated noise by spreading the noise profile over the power spectrum which in turn saves spatial complexity and alleviates **EMI** constraints.

Could potentially promise a compromise between system component sizes and control complexity at unprecedented reasonable performance; therefore, a paradigm shift in control design for certain applications.

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THANK YOU