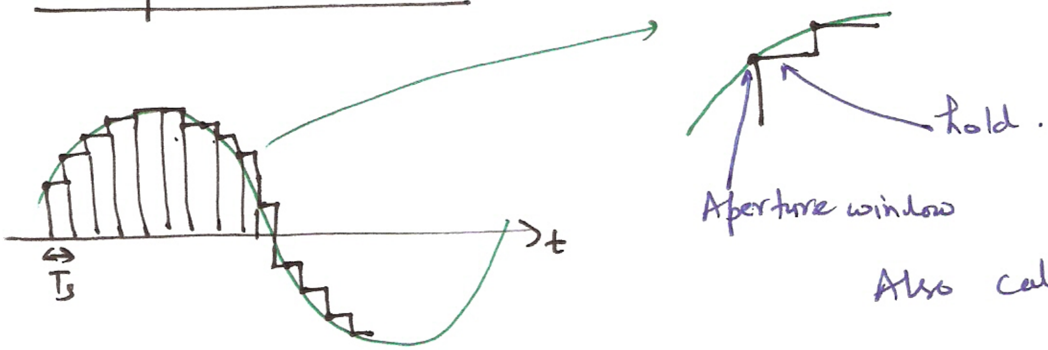
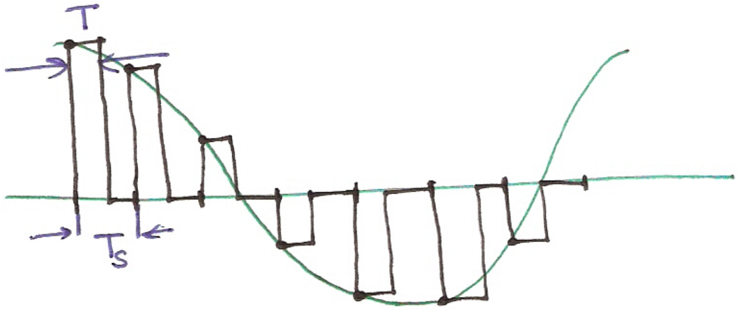
Sample and hold:



Also called zero-order hold (ZOH).
for NRZ pulse shape.

Ideal S/H → aperture window is sufficiently narrow w.r.t T_s

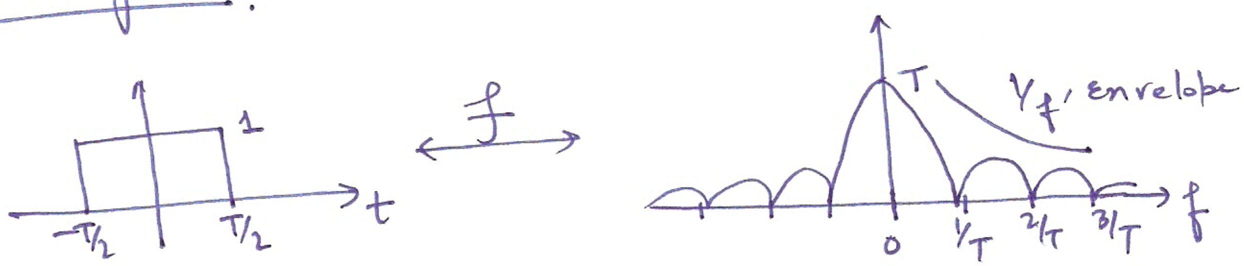
Generalized S/H.



RZ pulse width → T
sampling period → T_s

$0 < T \leq T_s$

* Recap on Signals.



$\text{rect}\left(\frac{t}{T}\right) \quad\quad T\,\text{sinc}(fT),$

$$\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

We have:

$$y(t) = \sum_{n=-\infty}^{\infty} x(nT_s) \cdot \text{rect}\left(\frac{t - T/2 - nT_s}{T}\right)$$

$$= \sum_{n=-\infty}^{\infty} \left[x(t) \cdot \delta(t - nT_s)\right] \circledast \text{rect}\left(\frac{t - T/2}{T}\right) \quad \leftarrow \text{Think here!}$$

$$= \Big[x(t) \cdot \underbrace{\sum_{n=-\infty}^{\infty} \delta(t - nT_s)}_{p(t)}\Big] \circledast \underbrace{\text{rect}\left(\frac{t - T/2}{T}\right)}_{h(t)}$$

$$= \left[x(t) \cdot p(t)\right] \circledast h(t)$$

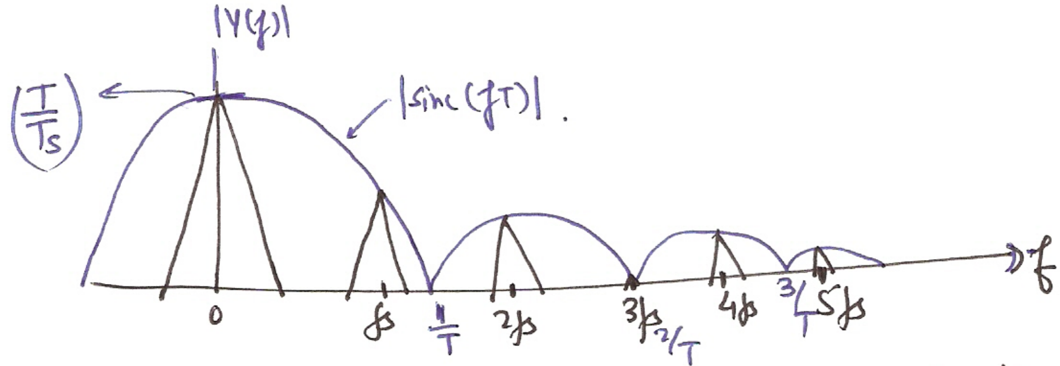
$$\Rightarrow Y(f) = \left[X(f) \circledast P(f)\right] \cdot H(f)$$

$$\longrightarrow H(f) = \mathcal{F}\left(\text{rect}\left(\frac{t - T/2}{T}\right)\right)$$

$$= T\,\text{sinc}(fT) \cdot e^{-j\pi f T}$$

$$\Rightarrow |H(f)| = T\,|\text{sinc}(fT)|.$$

$$\Rightarrow Y(f) = \left(\frac{T}{T_s} \sum_{k=-\infty}^{\infty} X(f - kf_s)\right) \cdot \underbrace{\text{sinc}(fT)}_{\text{sinc distortion!}} \cdot e^{-j\pi f T}$$



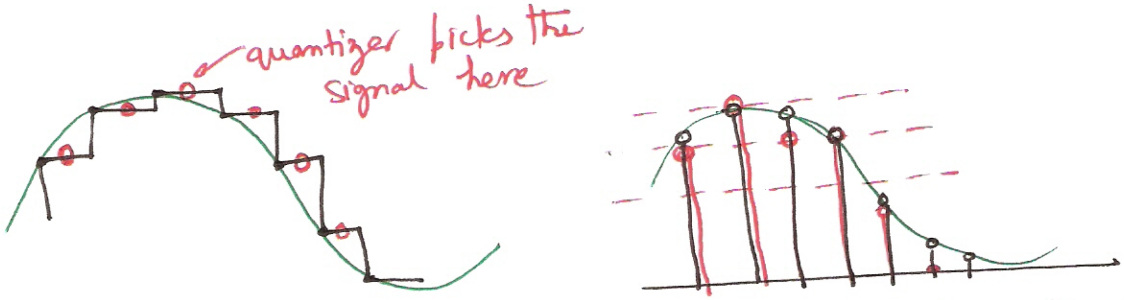
The replicas are weighted by the sinc response.

for $T = T_s \Rightarrow$ ZOH $\rightarrow$ worst Sinc distortion

for $\frac{T}{T_s} \rightarrow 0$, Sinc distortion vanishes but the output signal power of the S/H diminishes.

* Is the S/H's sinc distortion a problem in an ADC with a S/H in the front-end ??

Ans $\rightarrow$ No!



In an ADC, the quantizer senses the output of the front-end S/H only during the hold mode.

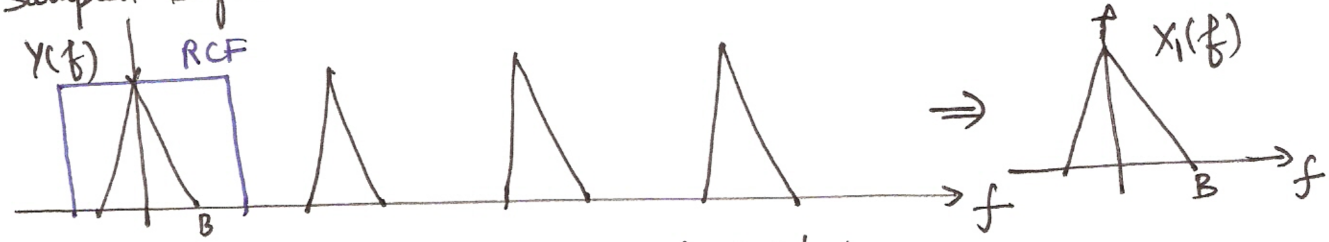
↳ the quantized value only corresponds to the sampled points on the input

$\Rightarrow$ Not an issue in the ADC!

BUT, the sinc distortion is an issue in a scenario where the sampler is following a DAC. (post-processing a DAC's output).

Reconstruction:

Sampled signal

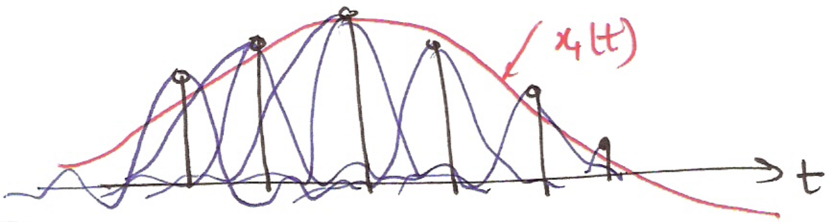


in time domain its a sinc interpolation

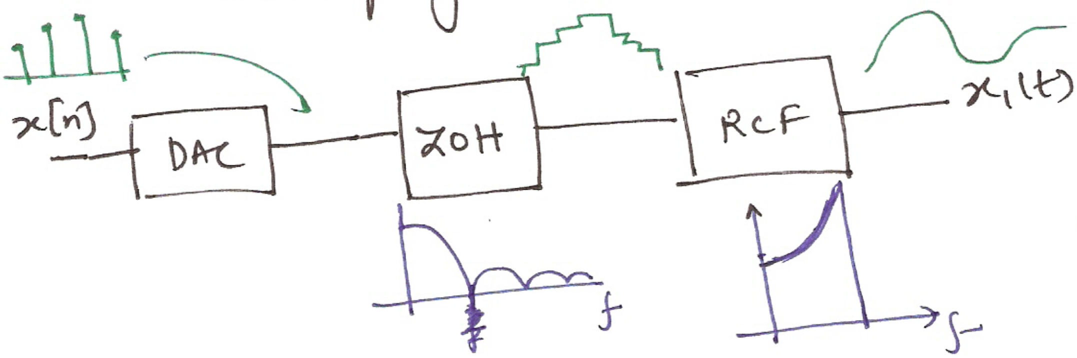
$$Y(f)\cdot rect\left(\frac{f}{B}\right) \xleftrightarrow{\mathcal{F}^{-1}} y(t) \circledast sinc(tB)$$

Using, $B\,sinc(tB) \xleftrightarrow{\mathcal{F}} rect\left(\frac{f}{B}\right)$

Duality property

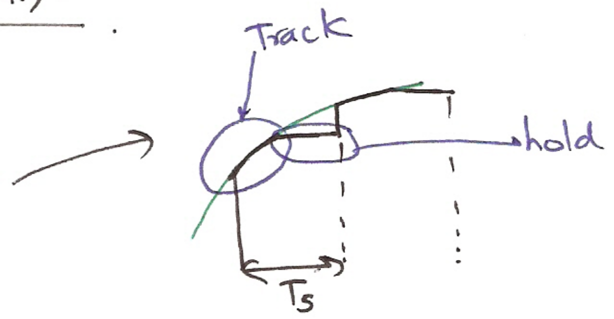


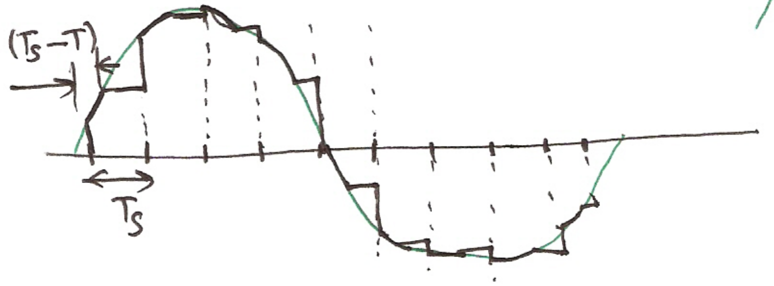
Again, the requirements on the RCF are relaxed by oversampling.



$sinc^{-1}$ response shape is used in the RCF to compensate for the sinc distortion in the ZOH

Track and hold (T/H).





$y(t)$ follows $x(t)$ during the track (aka acquisition) phase and is held during the hold phase

At high speeds (100 MHz → 10 GHz) the aperture time increases w.r.t the sample period
⇒ distinction between S/H and T/H dissappears at such speeds.
Ex. 10 GHz ADC all employ T/H's in the front-end.

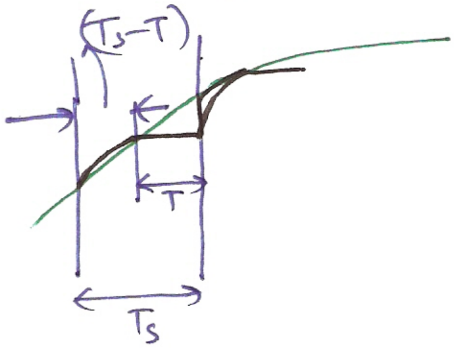
Analysis of T/H

$y(t) = y_T(t) + y_H(t)$ ← summation of two ~~responses~~ signals

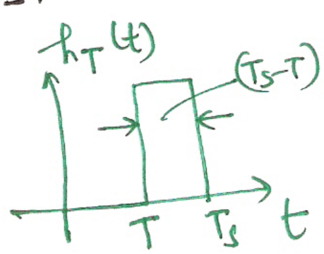
(track: y_T, ~~track~~ hold: y_H)

* $y_H(t)$ is same as in the RZ S/H response
* need to find $y_T(t)$

* Note that $y_T(t) = x(t) \cdot \left[h_T(t) \circledast \sum_{n=-\infty}^{\infty} \delta(t - nT_s) \right]$.



hold lasts for 'T'
track for '$T_s - T$'



$$\Rightarrow h_T(t) = \text{rect}\left(\frac{t - \left(\frac{T + T_s}{2}\right)}{(T_s - T)} \right)$$

REMAINING IS A HW PROBLEM !

ECE 697 Delta-Sigma Converters Design

Lecture#2 Slides

Vishal Saxena
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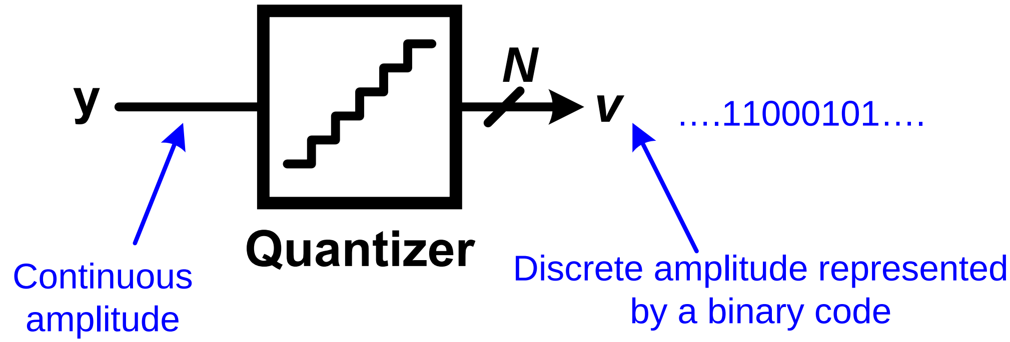
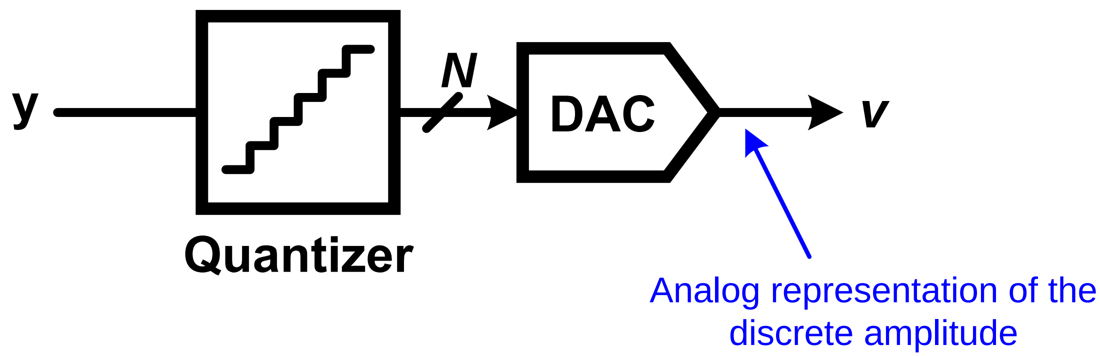
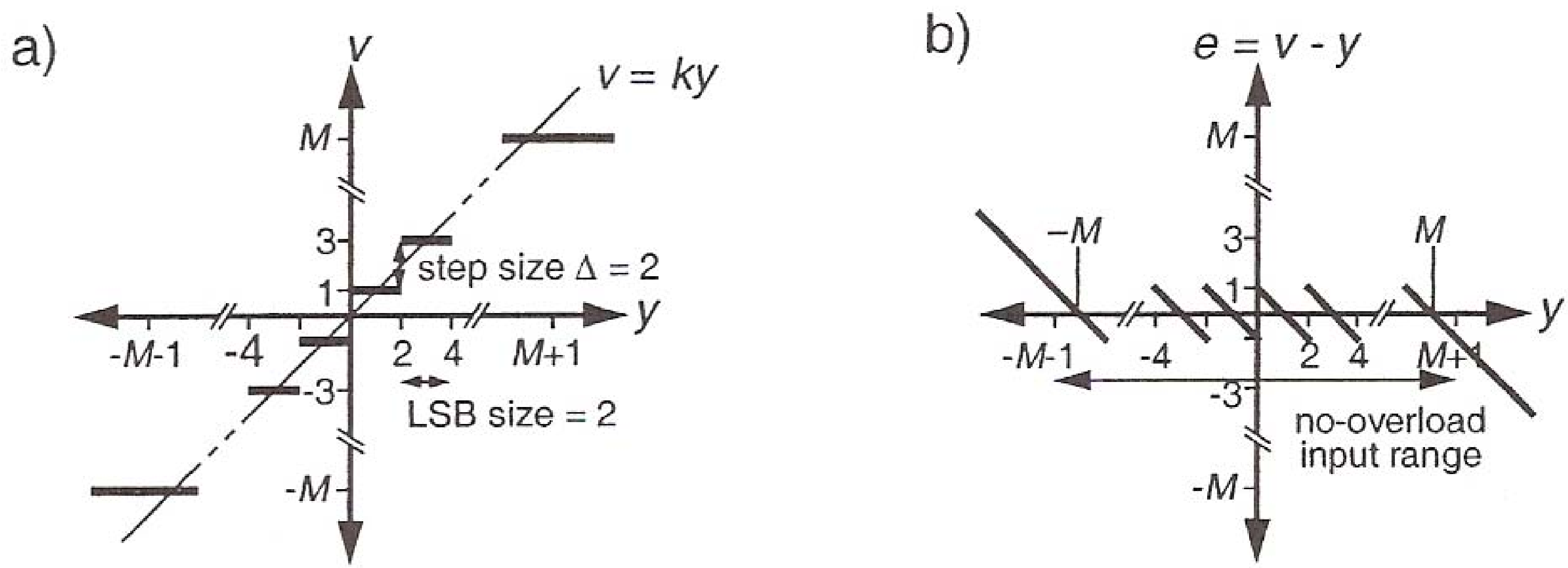
Quantizer



Modeling

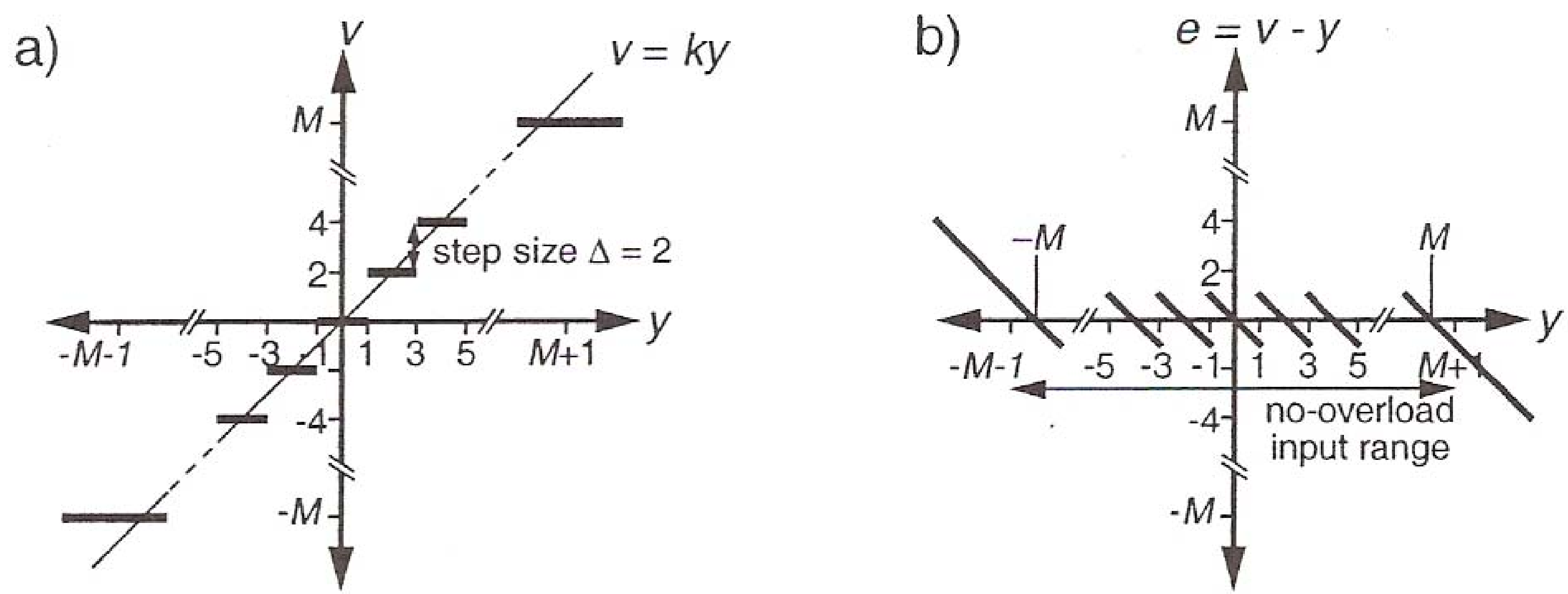


Mid-Rise Quantizer (even number of levels)



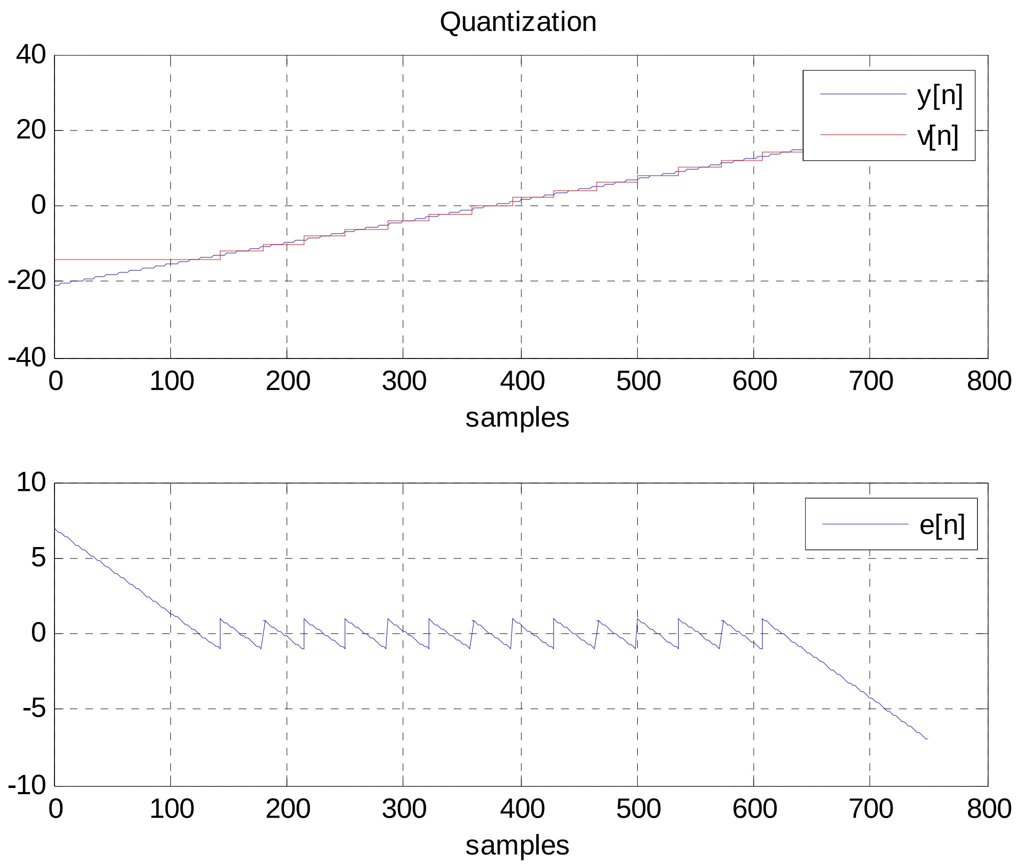
- Step rising at y=0 (mid-rise).
- In this figure (DSM toolbox model), LSB= Δ= 2
- M = Number of steps, (M is odd here)
  - Number of levels (nLev) = M+1, (even)
- Input thresholds: 0, ±2, ……, ±(M–1).
- Output levels: ±1, ±3, ……, ±M.

Mid-Tread Quantizer (odd number of levels)



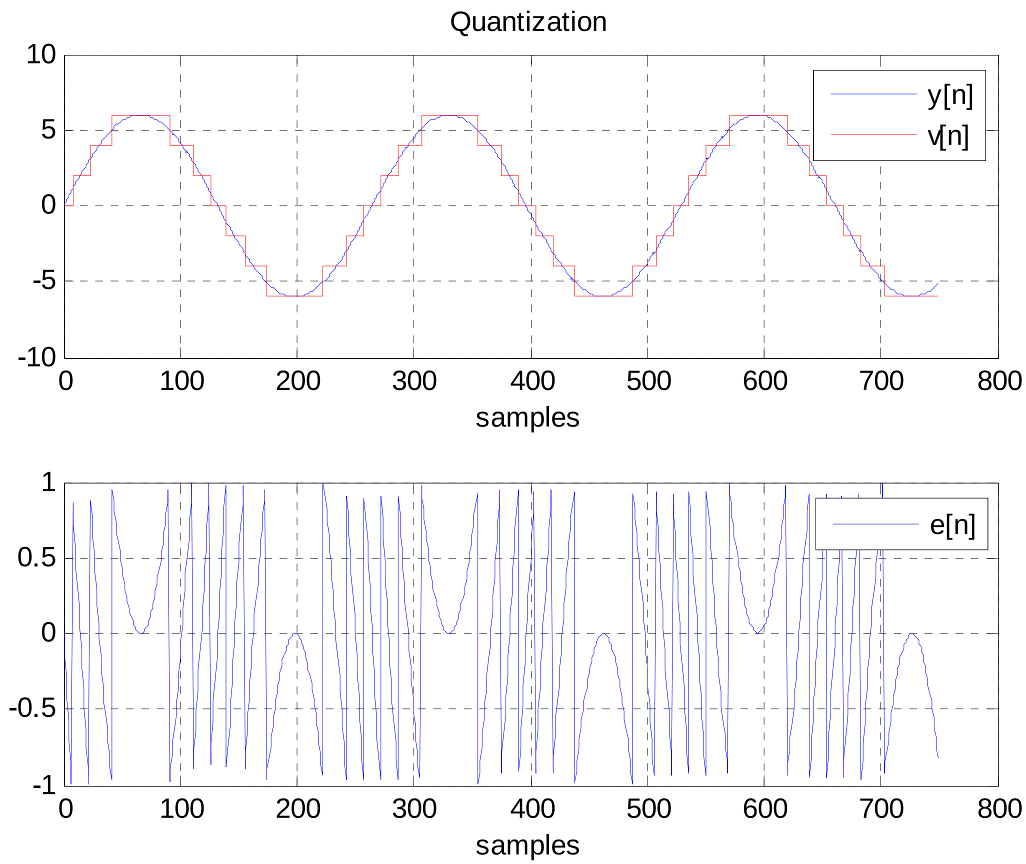
- Flat part of the step at y=0 (mid-tread).
- Here, LSB= Δ= 2
- M = Number of steps, (M is even here)
  - ✓ Number of levels (nLev) = M+1, (odd)
- Input thresholds: 0, ±2, ……, ±(M–1).
- Output levels: 0, ±2, ±4, ……, ±M.

Quantizer characteristics : Slow ramp input



File: Quantizer_ramp_input.m

Quantizer characteristics : Sine input



File: Quantizer_sine_input.m