Experiment 8
Delta Modulation (PCM)
Part 1

Prepared by

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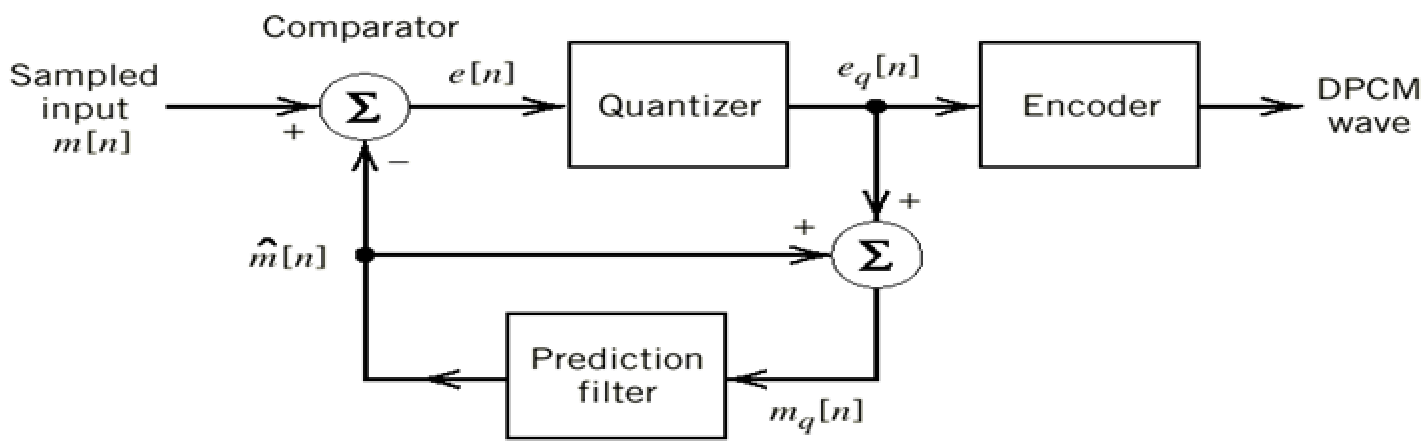
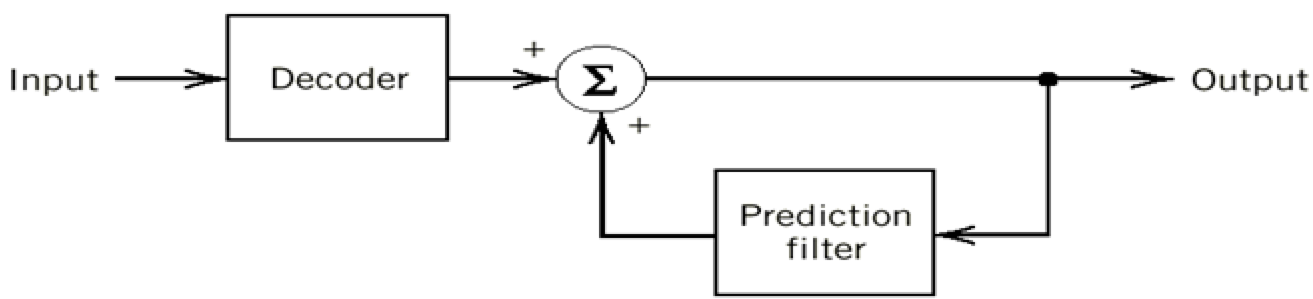
Delta Modulation

- Delta modulation (DM), is a special case of the DPCM.
- The order of the prediction filter is p=1 (and represents only the quantized value of the previous sample)
- In this scheme, the system transmits the sign of the difference between the current and previous samples. The sign is represented by a single bit.





Delta Modulation: Basic Operation

Let $m[n] = m(nT_s)$, $n = 0, \pm 1, \pm 2, \ldots$

where T_s is the sampling period and $m(nT_s)$ is a sample of $m(t)$.

The error signal is

$$e[n] = m[n] - m_q[n-1]$$

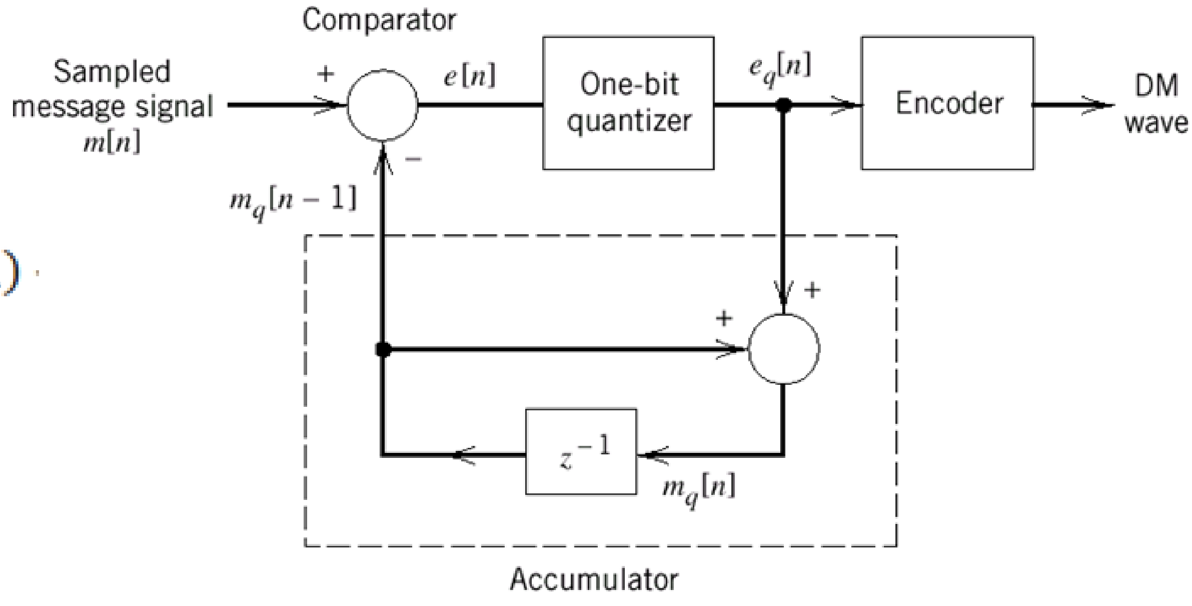
$$e_q[n] = \Delta \operatorname{sgn}(e[n]); \text{ quantized error}$$

$$m_q[n] = m_q[n-1] + e_q[n]$$

where $m_q[n]$ is the quantizer output ,$e_q[n]$ is the quantized version of $e[n]$,

and Δ is the step size

$$\hat{x}(n) = w_1 x(n-1)$$

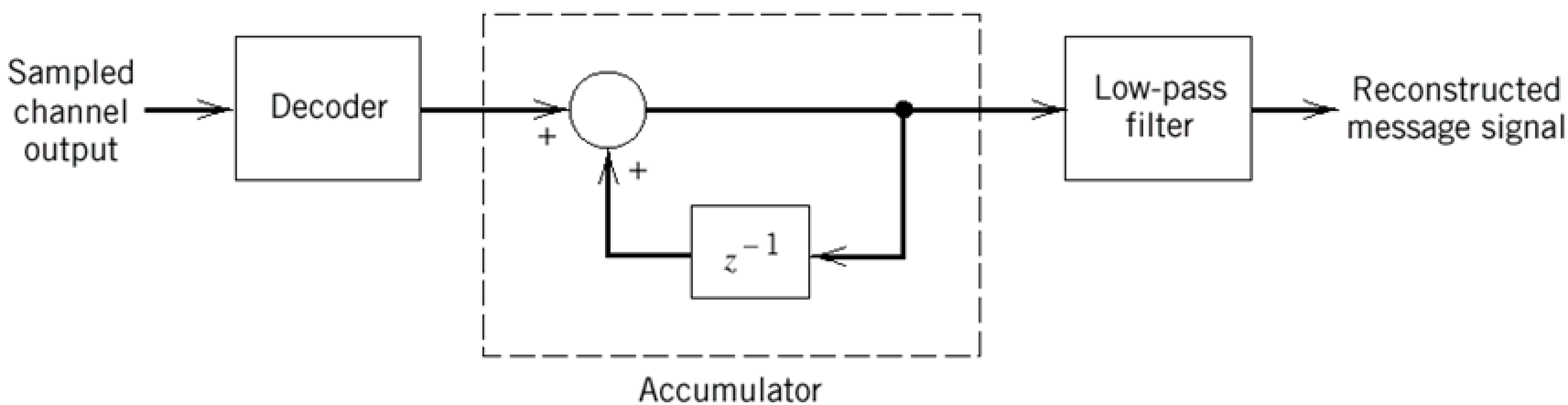


Delta Modulation: Basic Operation

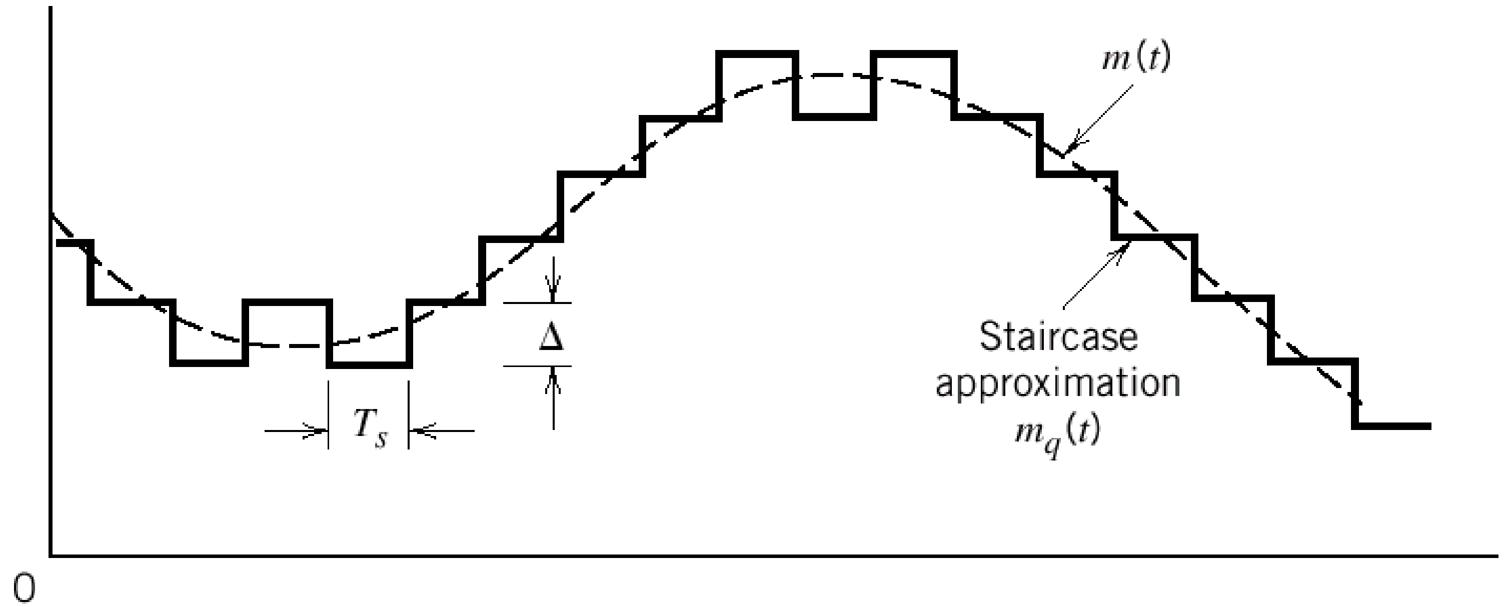
$$m_q[n] = m_q[n-1] + e_q[n]$$

$$\Rightarrow m_q[n] = \Delta \sum_{i=1}^{n} \text{sgn}(e[i])$$

$$= \sum_{i=1}^{n} e_q[i]$$



Delta Modulation: Basic Operation

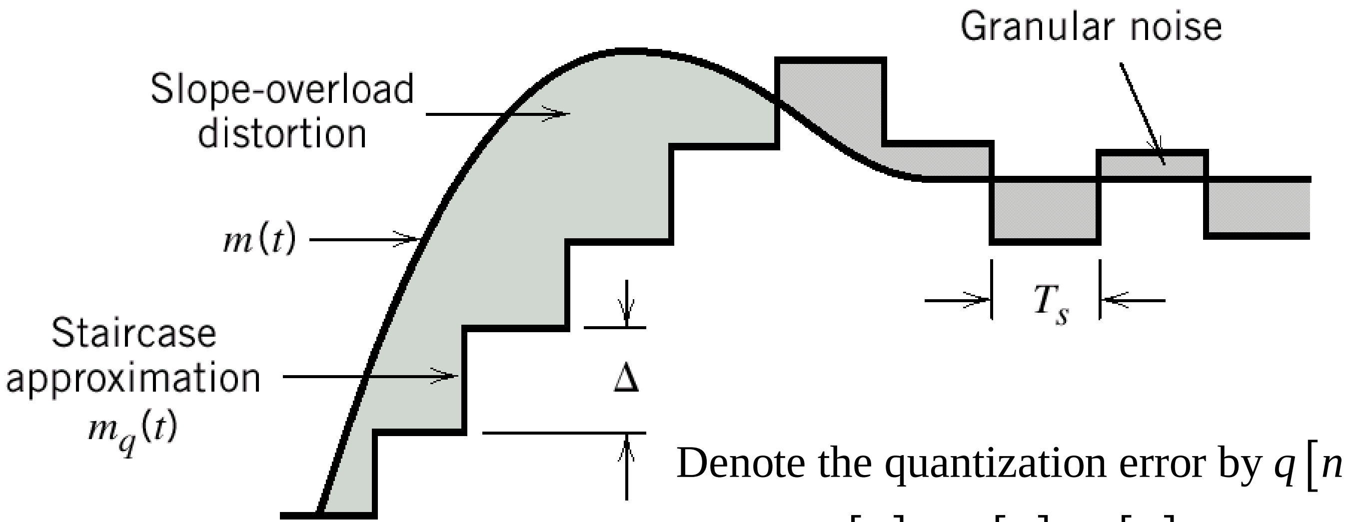


(a)

Binary sequence at modulator output 0 0 1 0 1 1 1 1 1 0 1 0 0 0 0 0 0

(b)

Slope overload distortion and granular noise



Denote the quantization error by $q[n]$,

$$m_q[n] = m[n] - q[n]$$

We have

$$e[n] = m[n] - m[n-1] - q[n-1]$$

Except for $q[n-1]$, the quantizer input is a first backward difference of the input signal (i.e., a differentiator)

To avoid slope-overload distortion , we require

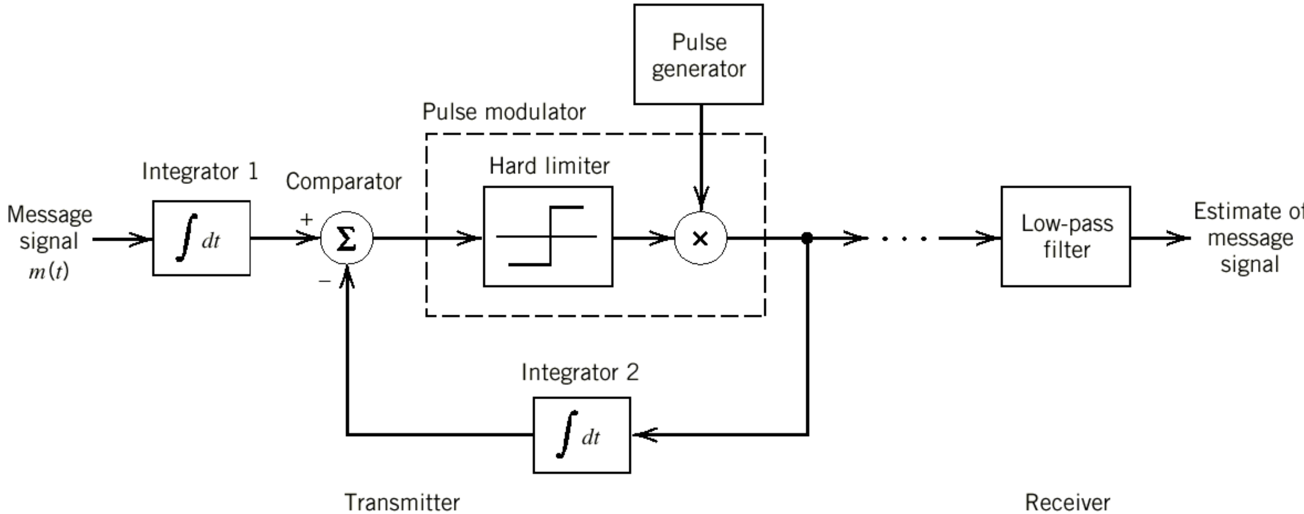
(slope) $$\frac{\Delta}{T_s} \geq \max\left|\frac{dm(t)}{dt}\right|$$

On the other hand, granular noise occurs when step size Δ is too large relative to the local slope of $m(t)$.

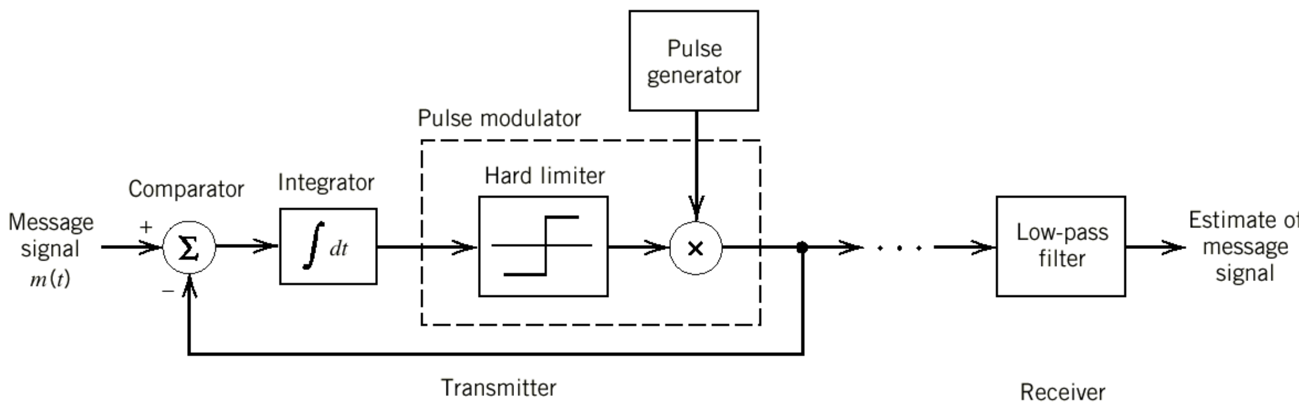
Delta-Sigma modulation (sigma-delta modulation)

- The modulation which has an integrator can relieve the drawback of delta modulation (differentiator)
- Beneficial effects of using integrator:
- Pre-emphasize the low-frequency contents of the message $M(f)/j2\pi f$. Low frequencies are enhanced while high frequencies are attenuated.
- Increase correlation between adjacent samples (reduce the variance of the error signal at the quantizer input)
- Simplify receiver design because the transmitter has an integrator, the receiver consists simply of a low-pass filter. (The differentiator in the conventional DM receiver is cancelled by the integrator)

Delta-Sigma modulation (sigma-delta modulation



(a)



(b)

Adaptive Delta Modulation

- The step size in delta modulation affects the quality of the transmitted waveform (slope overload or granular noise).
- A larger step-size is needed in the steep slope of modulating signal
- a smaller stepsize is needed where the message has a small slope
- In adaptive delta modulation, the step size is adjusted via a feedback control signal so as to reduce both slope overload and granular noise effects.

Adaptive Delta Modulation

- The gain of the voltage controlled amplifier is adjusted by the output signal from the sampler. The amplifier gain determines the step-size.
- ADM quantizes the difference between the value of the current sample and the predicted value of the next sample. It uses a variable step height to predict the next values, for the faithful reproduction of the fast varying values.