MBI

OVERSAMPLING

MULT-BIT QUANTIZERS

ADVANTAGES

1) QUANTIZATION ERROR REDUCED BY 6dB FOR EVERY BIT ADDED TO QUANTIZER RESOLUTION

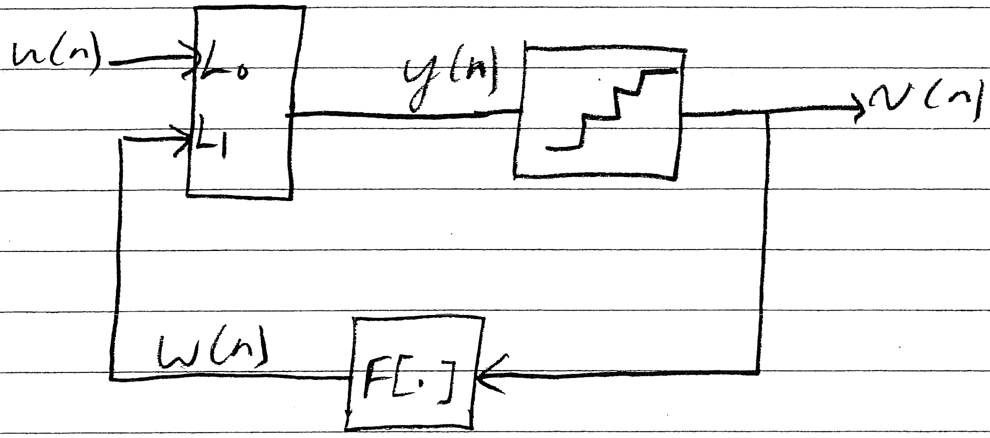
2) SYSTEM MORE LINEAR SO NTF CAN BE MORE AGGRESSIVE
$\Rightarrow$ LESS NOISE IN BAND
EX 5'TH ORDER MOD WITH OSR = 16
1B $\Rightarrow$ MAX SQNR = 60dB
4B $\Rightarrow$ " " = 120dB

3) LESS SLEW RATE REQUIRED FOR INPUT OPAMP

4) FOR CONT-TIME $\Delta\Sigma$ LOOP FILTERS, LESS SENSITIVE TO CLOCK JITTER SINCE SMALLER DAC STEPS.

DISADVANTAGE

DAC MUST BE LINEAR TO OVERALL LINEARITY DESIRED



DAC TRANSFER FUNCTION

$$w(n) = F[v(n)]$$

IN BAND $\Rightarrow$ $w(n) = u(n)$

$$F[v(n)] = u(n)$$

$$v(n) = F^{-1}[u(n)]$$

IF $F[\cdot]$ IS NON-LINEAR THEN

$v(n)$ IS NON-LINEAR RELATION TO $u(n)$

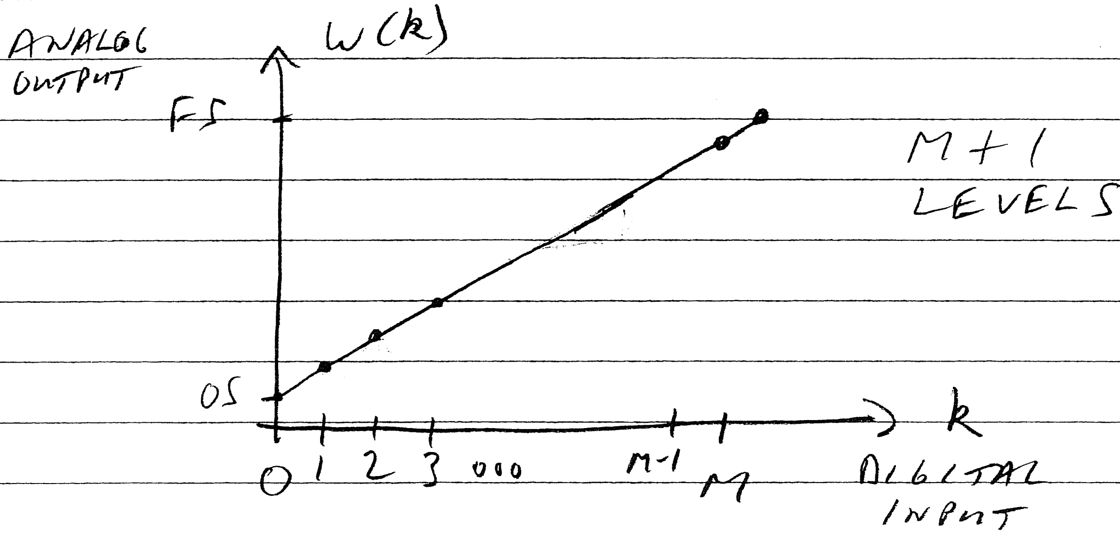
MB3

DYNAMIC ELEMENT RANDOMIZATION

SINCE OVERSAMPLED, CAN MAKE AVERAGE DAC LINEAR ALTHOUGH (FOR LOWPASS)

ALTHOUGH DAC NON-LINEAR AT EACH INSTANCE.

CONSIDER IDEAL $W(k)$ WHICH HAS OFFSET AND GAIN ERROR (UNIPOLAR CASE)



$$W(k) = OS + \frac{FS - OS}{M} k \qquad (1)$$

DAC BUILT USING M UNIT SIZE ELEMENTS AND WHERE EACH ELEMENT IS

u_i

LET $\boxed{u_i \equiv u + d_i}$ (2)

WHERE u IS AVERAGE ELEMENT VALUE

$$u \equiv \frac{1}{M}\sum_{i=1}^{M} u_i \quad (3)$$

AND d_i ARE DEVIATIONS OF u_i FROM THE AVERAGE u

FROM (3) $$u = \frac{1}{M}\sum_{i=1}^{M} u + \frac{1}{M}\sum_{i=1}^{M} d_i$$

$$u = u + \frac{1}{M}\sum_{i=1}^{M} d_i$$

$$\Rightarrow \boxed{\sum_{i=1}^{M} d_i = 0} \quad (4)$$

ALSO FULL-SCALE OUTPUT IS

$$FS = OS + \sum_{i=1}^{M} u_i = OS + M\,u \quad (5)$$

FINALLY, IDEAL OUTPUT $w(k)$

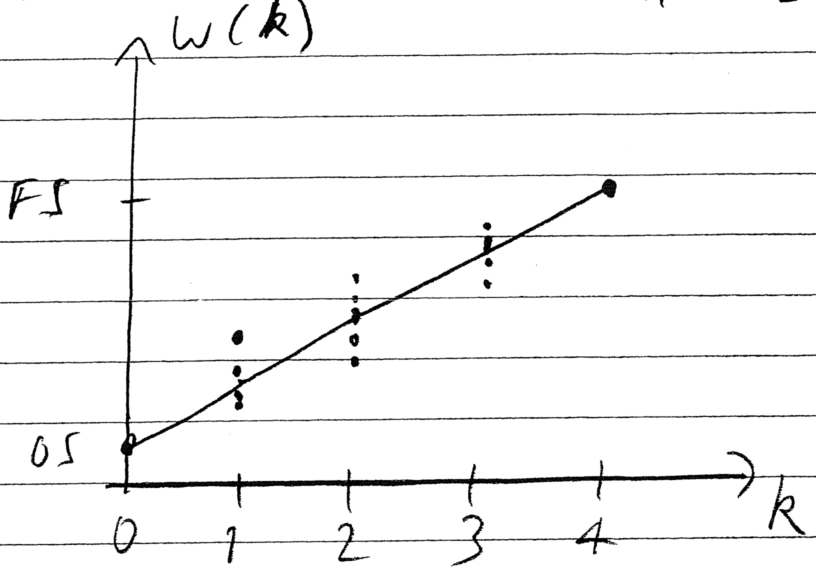
$$\boxed{w(k) = OS + k \cdot u} \quad (6)$$

(FROM (1) & (5))

MB5

CONSIDER CASE OF $M = 4$

$u_1 \quad u_2 \quad u_3 \quad u_4$



ONLY ONE POSSIBILITY AT $k = 0$ + $k = 4$

$k = 0$ ALL NOT USED

$k = 4$ $u_1 \; u_2 \; u_3 \; u_4$ USED

FOR $k = 1 \Rightarrow 4$ POSSIBLITIES

u_1

u_2

u_3

u_4

$$W(1) = OS + u_i \quad \text{WHERE } i = 1, 2, 3, \text{ OR } 4$$

AVERAGE

$$\overline{W}(1) = OS + \frac{1}{4} \sum_{i=1}^{4} u_i$$

$$= OS + \frac{1}{4} \sum_{i=1}^{4} (u + d_i)$$

$$\overline{W}(1) = OS + U + \frac{1}{4}\sum_{i=1}^{4} d_i$$

$$\overline{W}(1) = OS + U$$ AS EXPECTED

FOR $k=2 \Rightarrow$ 6 POSSIBILITIES

$u_1 + u_2$
$u_1 + u_3$
$u_1 + u_4$
$u_2 + u_3$
$u_2 + u_4$
$u_3 + u_4$

$$W(2) = OS + u_i + u_j$$

WHERE $i \neq j$
$i = 1, 2, 3,$ OR 4
$j = 1, 2, 3,$ OR 4

$$\overline{W}(2) = OS + \frac{3}{6}\sum_{i=1}^{4} u_i$$

$$= OS + 0.5\left[4u + \sum_{i=1}^{4} d_i\right]$$

$$= OS + 2u$$ AS EXPECTED

SIMILAR FOR $\overline{W}(3)$

SO IF ELEMENTS CHOSEN FOR $W(k)$ ARE RANDOMIZED $\Rightarrow$ THE AVERAGE VALUE OF $W(k)$ EQUALS THE IDEAL VALUE

(TRUE IN GENERAL)

ELEMENT SELECTION ALGORITHMS

1) RANDOM
2) DATA WEIGHTED AVERAGING (DWA)
3) INDIVIDUAL LEVEL AVERAGING (ILA)
4) VECTOR BASED MISMATCH SHAPING
5) ELEMENT SELECTION USING TREE STRUCTURE.

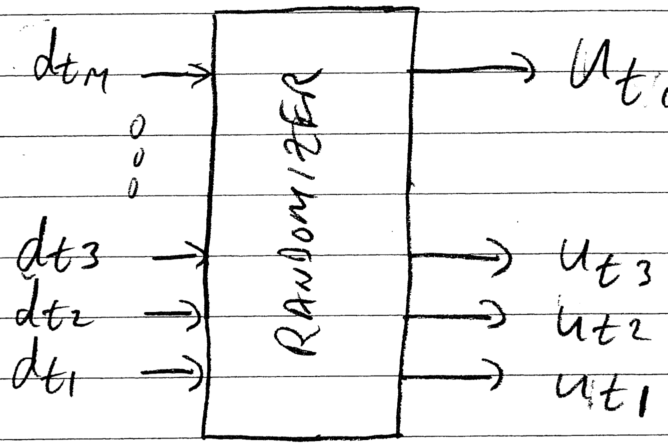
MB8

1) RANDOM

LET $k = v(n)$ BE REPRESENTED BY THERMOMETER CODE

$d_{ti} \quad i = 1, M \qquad d_{ti} = \text{"1" OR "0"}$

$$k = \sum_{i=1}^{M} d_{ti}$$



$$\text{SO} \quad k = \sum_{i=1}^{M} d_{ti} = \sum_{i=1}^{M} u_{ti}$$

IF $u_{ti} = 1$ THEN u_i USED

$u_{ti} = 0$ THEN u_i NOT USED

$$w(k) = \sum_{i=1}^{M} u_{ti}\, u_i$$

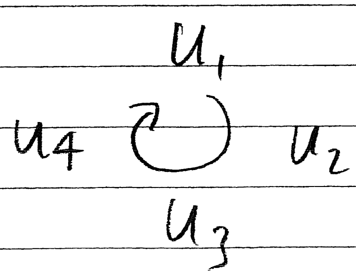
WHILE THIS WORKS, IT DOES NOT NOISE SHAPE NON-LINEARITIES

2) DWA (DATA WEIGHTED AVERAGING)

ROTATE ELEMENTS IN DAC

Ex IF $M = 4$

k	$w(k)$
1	u_1
2	$u_2 \ u_3$
0	
3	$u_4 \ u_1 \ u_2$
4	$u_3 \ u_4 \ u_1 \ u_2$
1	u_3
⋮	⋮



- FIRST ORDER NOISE SHAPING OF NON-LINEARTIES

- COULD HAVE PATTERN "NOISE"
- CAN INTRODUCE PSEUDO-RANDOM EFFECT.

MB10

3) ILA

FOR EACH CODE k, CHOOSE NEXT PATTERN SO ALL ARE USED AS QUICK AS POSSIBLE

CONSIDER $k=2$, $M=2$

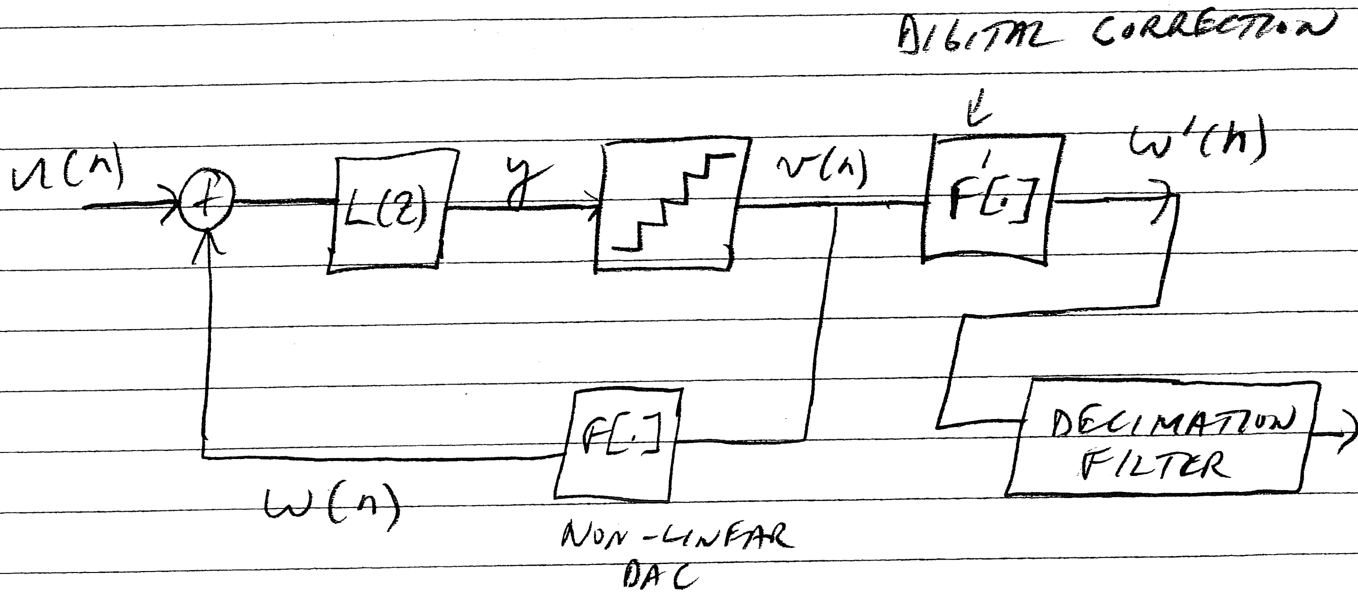
u_1 u_2
u_1 u_3
u_1 u_4
u_2 u_3
u_2 u_4
u_3 u_4

ROTATE THROUGH EACH TIME $k=2$

$\Rightarrow$ CONVERGES MORE SLOWLY TO LINEAR AVERAGE. THAN DWA

4) VECTOR
5) TREE
} READ

DIGITAL CORRECTION DAC NON-LINEARITY



SINCE IN BAND $w(n) = u(n)$

IF $F'[\cdot] = F[\cdot]$

THEN $w'(n) = w(n) = u(n)$ IN-BAND

$F'[\cdot]$ IS LOOK-UP TABLE TO MATCH DAC OUTPUTS

CALIBRATION NEEDED TO MATCH

$F'[\cdot]$ WITH $F[\cdot]$