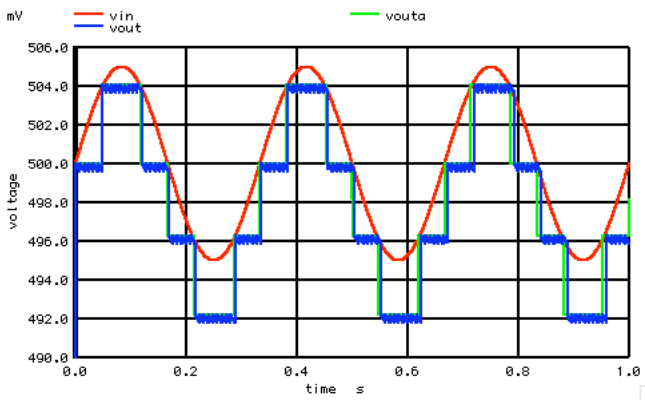
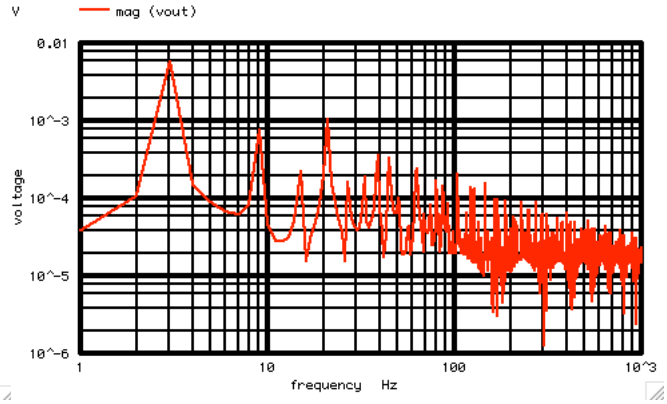
==========Quantization_Error_ADC==========

1) The human ear has a dynamic range from 0dB (which is the noise level of air) to 196dB (one atmosphere = destructive!)
2) Digital audio first came out at 16Bits (which is 96dBs).
3) Signal at the LSB level does develop nasty harmonics which mix with other signal.





Here a input signal at a +/2 LSB level is applied. The distortion it produces can mix with other sound to sound very unnatural.

==========MacSpiceCode==========

Quantization_Error_ADC

```
*
*       VIN
*
*    ___________ TH0 ___________ TH1 ___________ TH0 ___________ TH1 ___________ TH0 ___________ TH1 ___________ TH0 ___________ TH1
*   /_|_\       _/_|_\       _/_|_\       _/_|_\       _/_|_\       _/_|_\       _/_|_\       _/_|_\       _/_|_\
*  //|\ \\     |\ \|/ /|     |\ \|/ /|     |\ \|/ /|     |\ \|/ /|     |\ \|/ /|     |\ \|/ /|     |\ \|/ /|     |\ \
*  \ \_/ //     |_\ \_/_|     |_\ \_/_|     |_\ \_/_|     |_\ \_/_|     |_\ \_/_|     |_\ \_/_|     |_\ \_/_|     |_\_/_|
*   \_|_/        |/ | \|       |/ | \|       |/ | \|       |/ | \|       |/ | \|       |/ | \|       |/ | \|       |/ | \|
*    ///         |  |  |  OFF0 |  |  |  OFF1 |  |  |  OFF2 |  |  |  OFF3 |  |  |  OFF4 |  |  |  OFF5 |  |  |  OFF6 |  |  |
*                |D0|  |       |D1|  |       |D2|  |       |D3|  |       |D4|  |       |D5|  |       |D6|  |       |D7|  |
*                |__|  |       |__|  |       |__|  |       |__|  |       |__|  |       |__|  |       |__|  |       |__|  |
*
*
*          _______
*         __|      \
*         __|       \
*         __|  DAC   \__ VOUTA
*         __|       /
*         __|      /
*         __|_____/
*
*
*   VOUTA      IN2
*    ___      |\    /          IN3 |\
*   |IN |-|1\__/ S1  ____________|2\____|OUT|
*   |___|  |/      _|_           |/    |___|
*                  ___
*              C1 |___|
*                  ///
```

```
*=========Create_Signal==================
*V_SIN#    NODE_P NODE_N DC      VALUE  SIN(    V_DC    AC_MAG FREQ    DELAY  FDamp)
VIN        VIN    0      DC      0      SIN(    .5      .005     3                )
*V_PULSE#  NODE_P NODE_N DC      VALUE  PULSE( VINIT   VPULSE TDELAY TRISE  TFALL  PWIDTH PERIOD )
VCLKL      CLK    0      DC      0      PULSE( 0      1      1n     1n     1n     4m     8m     )

XPOSE1     CLK    CNTL           POS_E
XS_H1      VOUTA  CNTL   VOUT    SH

BTH0       D0     0      V =     u( V(VIN) -1/2)
BOFF0      VIN    OFF0   V =     V(D0)/2
BTH1       D1     0      V =     u( V(OFF0) -1/4)
BOFF1      OFF0   OFF1   V =     V(D1)/4
BTH2       D2     0      V =     u( V(OFF1) -1/8)
BOFF2      OFF1   OFF2   V =     V(D2)/8
BTH3       D3     0      V =     u( V(OFF2) -1/16)
BOFF3      OFF2   OFF3   V =     V(D3)/16
BTH4       D4     0      V =     u( V(OFF3) -1/32)
BOFF4      OFF3   OFF4   V =     V(D4)/32
BTH5       D5     0      V =     u( V(OFF4) -1/64)
BOFF5      OFF4   OFF5   V =     V(D5)/64

BTH6       D6     0      V =     u( V(OFF5) -1/128)
BOFF6      OFF5   OFF6   V =     V(D6)/128

BTH7       D7     0      V =     u( V(OFF6) -1/256)
BOFF7      OFF6   OFF7   V =     V(D7)/245

BDAC       VOUTA  0      V =     V(D0)/2+V(D1)/4+V(D2)/8+V(D3)/16+V(D4)/32+V(D5)/64+V(D6)/128+V(D7)/245
```

.control

```
*TRAN      TSTEP  TSTOP  TSTART TMAX   ?UIC?
tran       .05m    1      0      .05m
set        pensize = 2
plot       vin  vouta vout xlimit 1ms 1

plot       vin -vout xlimit 1ms 1

echo               "==================FFT_and_Plot======================================"
linearize
let                FFT_BandWidth_Hz =  1k
let                FFT_resolution_Hz = 1
echo               "FFT_BandWidth_Hz=  $&FFT_BandWidth_Hz"
echo               "FFT_resolution_Hz= $&FFT_resolution_Hz"
set                specwindow =         "rectangular"
spec               $&FFT_resolution_Hz  $&FFT_BandWidth_Hz   $&FFT_resolution_Hz     v(vout)
plot               mag (vout)   loglog
*plot              mag (vout)  ylog xlimit 400 600
echo               "plot               fft eye_chart"
echo               "==================Done=============================================="

.endc

*=========Sample_Hold==========================================
*
*            IN2
*        |\    /         IN3 |\
*   |IN|-|1\__/  ____________|2\____|OUT|
*   |__|  / S1   _|_         |/     |___|
*        |/      ___         |/
*                C1 |
*                   |
*                  ///
.SUBCKT    SH      IN      CNTL      OUT
 B1        IN2     0       V =       v(IN )
 S1        IN2     IN3     CNTL     0    SW
 C1        IN3     0       .1u

 R1        IN3     0       100Meg
 B2        OUT     0       V =       v(IN3 )
.ENDS      SH


*=========POS_Edge============================================
*
*        |\             VBF ____
*  |IN|__|3\_____________|    \
*  |__|  / |             VLP| PE \_|OUT|   |IN|_|PE \_|OUT|
*        |/  |/\  /\  /\___|    /  |___|   |__|  /  |___|
*              \/  \/      |___/              |__/
*              RLP         _|_
*                          ___
*                    CLP  |
*                         |
*                         ///
*
.SUBCKT    POS_E   IN      OUT
 BBUF      VBF     0       V =   u( v(IN )-.5 )
 RLP       VBF     VLP     10k
 CLP       VLP     0       1n   IC=0
 BAND      OUT     0       V =    u( u(v(VBF )-.5)*u(.5 -v(VLP ) ) -.1)
.ENDS      POS_E

.MODEL     SW      SW(     VT=.5 VH=.1  RON=1 ROFF=100MEG)


.end

4.4.11_12.34PM
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```