

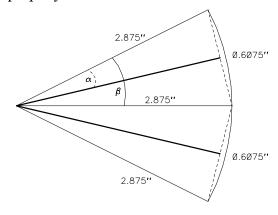
Application Note AN3201-01: Off-Center 45RPM Record by Chris Maple

Introduction

To illustrate the range of frequency sweeping possible with the DRE, this application note provides an effect similar to placing a 45 rpm phonograph record - the kind with the large hole - off-center by the greatest amount possible on a turntable with a standard 0.285" spindle.

Algorithm

The hole on a 45 rpm record is 1.5" in diameter. If the record is moved off center so that the edge of the hole touches the spindle, the record will be 0.5*(1.5"-0.285") = 0.6075" off-center. A typical distance from the center of the record to the stylus is 2.875" (about 1/3 of the way through a song that fills up as much of the record as possible). Approximating the geometric functions involved, the stylus position will be as much as 0.6075" ahead or behind of where it would be if the record were properly centered.



To figure out the time deviation, we first need to calculate the deviation distance. In the figure above, the two dashed lines show the maximum variation of the stylus position, at 0.6075". The three thin lines are the radius line to the maximum positive, maximum negative, and zero variation points, with the typical distance of 2.875". The deviation distance may be determined as follows:

 \Rightarrow The center and one outer edge thin line, plus its connecting dashed line, form an equilateral triangle. By bisecting the corner angle β with the thick line, we may calculate the half angle α thus formed with the formula $\sin(\alpha)$ = length of opposite side / length of hypotenuse. To simplify the math, we use the approximation that $\sin(\alpha) \approx \alpha$ for small angles.

 $\beta = 2*\alpha \approx 2*\sin(\alpha) = 2*(0.6075"/2)/2.875" = 0.2113 \text{ radians}$

0.2113 radians / 2π radians in a circle = 0.03363 of the circumference

 \Rightarrow Using the distance, plus the speed of the record (45rpm, or 0.75rps), the time deviation may be determined.

0.03363/0.75rps = 44.84ms

At 48000 samples/second, 44.84ms is 2152.33 samples ahead or behind. For a stereo record, the right channel is the outer wall of the groove and is about 1 mil further from the center of the record than the left channel. Allowing the previous result to be the left channel, the variations for the right channel are a little smaller, 2151.58 samples.

The output of a magnetic phonograph cartridge is proportional to velocity, so as the sound pitches up the amplitude will rise. However, this is mostly compensated for by the RIAA playback response, which declines with rising frequency. Thus for a gross effect such as this, there's no need to attempt to change the amplitude.

The severely misaligned stylus will produce distortion, this also is not simulated.

The running-ahead of the audio will be duplicated by pitching up the audio and the running-behind by pitching down. Pitching up results in the possibility of aliasing. To prevent this, the program includes an anti-aliasing filter with a cutoff frequency of approximately 19kHz. The filter has only moderate out-of-band rejection; a better filter could be designed and implemented in the DRE, with some difficulty, as the limited coefficient range of the DRE makes implementing high quality filters difficult. The strength of the DRE is in its high quality, wide range digital oscillators and the functions that can be derived from them, thus the filter consumes most of the code, and the varying pitch shift only a small part.

The frequency coefficient for the oscillators is 26, implying a 45.46 rpm rate for the "record", which is as close as the DRE can come to 45 rpm with a sample rate of 48000 per second. The left channel amplitude is $2152.33 \times 8 \approx 17219$, the right channel $2150.58 \times 8 \approx 17213$.

Source Code

```
;LEFT, 45.46 RPM
LFO0
      SIN
             AMP=17219
                          FREO=26
LF01
      SIN
             AMP=17213
                          FREO=26
                                              ; RIGHT
MEM
      BUFL 17
                          ;left channel input-FIR buffer
MEM
      SWMEML 4400
                          ;left channel sweep memory
MEM
      BUFR 17
MEM
      SWMEMR 4400
                                 ;read left channel input
RZP
      ADCL
                   K = 127
WZP
      BUFL
                   K=1
                                 ; write input to FIR buffer, first FIR coefficient
RAP
      BUFL+1
                   K=-2
                                 ; second FIR stage
                   K = 2
RAP
      BUFL+2
RAP
      BUFL+3
                   K=-1
RAP
      BUFL+4
                   K = -3
RAP
                   K = 10
      BUFL+5
                   K = -18
RAP
      BUFL+6
RAP
      BUFL+7
                   K = 25
      BUFL+8
                   K = 100
RAP
      BUFL+9
                   K = 25
RAP
RAP
      BUFL+10
                   K = -18
RAP
      BUFL+11
                   K = 10
                   K = -3
RAP
      BUFL+12
RAP
      BUFL+13
                   K = -1
RAP
      BUFL+14
                   K=2
RAP
      BUFL+15
                   K=-2
RAP
      BUFL+16
                   K=1
WZP
      SWMEML
                   K=0
                                 ; save FIR output to beginning of sweep memory
                   +SIN LATCH COMPK
CHRO RZP SWMEML"
                                          ;get data at swept memory address, scale
CHR0 RAP SWMEML"+1 +SIN
                                       ;add (1-scale)x(data) at next address
WAP
      OUTL
                   K=0
                                       ;write result to left output
```



```
RZP
      ADCR
                   K = 127
                                 ;read right channel input
                                 ; write input to FIR buffer, first FIR coefficient
WZP
      BUFR
                   K=1
RAP
      BUFR+1
                   K=-2
                                 ;second FIR stage
RAP
      BUFR+2
                   K=2
RAP
      BUFR+3
                   K=-1
                   K=-3
RAP
      BUFR+4
RAP
      BUFR+5
                   K = 10
      BUFR+6
                   K = -18
RAP
                   K = 25
RAP
      BUFR+7
                   K = 100
RAP
      BUFR+8
RAP
      BUFR+9
                   K = 25
RAP
      BUFR+10
                   K = -18
      BUFR+11
                   K = 10
RAP
RAP
      BUFR+12
                   K=-3
RAP
      BUFR+13
                   K=-1
RAP
      BUFR+14
                   K=2
      BUFR+15
                   K=-2
RAP
RAP
      BUFR+16
                   K=1
WZP
      SWMEMR
                   K = 0
                                 ; save FIR output to beginning of sweep memory
                   LATCH
                                           ;get data at swept memory address, scale
CHR1 RZP SWMEMR"
                           +SIN
                                COMPK
CHR1 RAP SWMEMR"+1
                     +SIN
                                       ;add (1-scale)x(data) at next address
                                 ;write result to right output
WAP
      OUTR K=0
RZP
      BUFR+0x40
                   K=0
                                 ;refresh
RZP
      BUFR+0x80
                   K=0
                                 ;refresh
      BUFR+0xC0
                   K = 0
                                 ;refresh
RZP
                                 ;refresh
RZP
      BUFR+0x100
                   K=0
RZP
      BUFR+0x140
                   K=0
                                 ;refresh
RZP
      BUFR+0x180
                   K=0
                                 ;refresh
RZP
      BUFR+0x1C0
                                 ;refresh
                   K = 0
RZP
      BUFR+0x200
                   K=0
                                 ;refresh
RZP
      BUFR+0x240
                   K=0
                                 ;refresh
RZP
      BUFR+0x280
                   K=0
                                 ;refresh
                                 ;refresh
RZP
      BUFR+0x2C0
                   K=0
RZP
      BUFR+0x300
                   K=0
                                 ;refresh
RZP
      BUFR+0x340
                   K=0
                                 ;refresh
      BUFR+0x380
                                 ;refresh
RZP
                   K=0
RZP
      BUFR+0x3C0
                   K=0
                                 ; last refresh, END OF PROGRAM
```



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