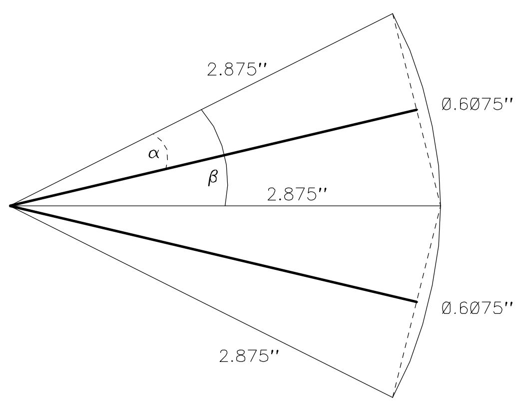
Application Note AN3201-01: Off-Center 45RPM Record
by Chris Maple

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:

⇒ 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.

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

$$0.2113 \text{ radians} / 2\pi \text{ radians in a circle} = 0.03363 \text{ of the circumference}$$

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

$$0.03363/0.75\text{rps} = 44.84\text{ms}$$

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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 x 8 ≈ 17219, the right channel 2150.58 x 8 ≈17213.

Source Code

```
LFO0  SIN   AMP=17219   FREQ=26           ;LEFT, 45.46 RPM
LFO1  SIN   AMP=17213   FREQ=26           ;RIGHT

MEM   BUFL  17          ;left channel input-FIR buffer
MEM   SWMEML 4400       ;left channel sweep memory
MEM   BUFR  17
MEM   SWMEMR 4400

RZP   ADCL        K=127       ;read left channel input
WZP   BUFL        K=1         ;write input to FIR buffer, first FIR coefficient
RAP   BUFL+1      K=-2        ;second FIR stage
RAP   BUFL+2      K=2
RAP   BUFL+3      K=-1
RAP   BUFL+4      K=-3
RAP   BUFL+5      K=10
RAP   BUFL+6      K=-18
RAP   BUFL+7      K=25
RAP   BUFL+8      K=100
RAP   BUFL+9      K=25
RAP   BUFL+10     K=-18
RAP   BUFL+11     K=10
RAP   BUFL+12     K=-3
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
CHR0 RZP SWMEML"  +SIN  LATCH  COMPK   ;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
WZP   BUFR        K=1         ;write input to FIR buffer, first FIR coefficient
RAP   BUFR+1      K=-2        ;second FIR stage
RAP   BUFR+2      K=2
RAP   BUFR+3      K=-1
RAP   BUFR+4      K=-3
RAP   BUFR+5      K=10
RAP   BUFR+6      K=-18
RAP   BUFR+7      K=25
RAP   BUFR+8      K=100
RAP   BUFR+9      K=25
RAP   BUFR+10     K=-18
RAP   BUFR+11     K=10
RAP   BUFR+12     K=-3
RAP   BUFR+13     K=-1
RAP   BUFR+14     K=2
RAP   BUFR+15     K=-2
RAP   BUFR+16     K=1
WZP   SWMEMR      K=0         ;save FIR output to beginning of sweep memory
CHR1 RZP SWMEMR"  LATCH  +SIN  COMPK   ;get data at swept memory address, scale
CHR1 RAP SWMEMR"+1  +SIN            ;add (1-scale)x(data) at next address
WAP   OUTR  K=0               ;write result to right output

RZP   BUFR+0x40   K=0         ;refresh
RZP   BUFR+0x80   K=0         ;refresh
RZP   BUFR+0xC0   K=0         ;refresh
RZP   BUFR+0x100  K=0         ;refresh
RZP   BUFR+0x140  K=0         ;refresh
RZP   BUFR+0x180  K=0         ;refresh
RZP   BUFR+0x1C0  K=0         ;refresh
RZP   BUFR+0x200  K=0         ;refresh
RZP   BUFR+0x240  K=0         ;refresh
RZP   BUFR+0x280  K=0         ;refresh
RZP   BUFR+0x2C0  K=0         ;refresh
RZP   BUFR+0x300  K=0         ;refresh
RZP   BUFR+0x340  K=0         ;refresh
RZP   BUFR+0x380  K=0         ;refresh
RZP   BUFR+0x3C0  K=0         ;last refresh, END OF PROGRAM
```

NOTICE

Contact Information:

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