

# <u>Application Note AN3201-03: Wide Stereo Chorus</u> by Jeff Rothermel

### Introduction

This application note describes a typical method for creating chorus effects on the DRE. A chorus effect adds a slowly time-varying delay and pitch (less than 1Hz) to an original voice to simulate additional voices (a chorus).

### Algorithm

The basic parameters of a chorus are the modulation depth, modulation rate and predelay. The DRE's LFOs are used in sine mode to modulate the delay of the signal. Maximum delay is determined by the amplitude of the LFO, or modulation depth. As the LFO sine wave crosses zero, maximum change in delay versus time results in maximum change in pitch. This rate of delay change is determined by both modulation depth and modulation rate. The generated chorus is added back to the original dry signal with a certain amount of constant pre-delay to avoid objectionable phase cancellation artifacts.

A chorus effect requires delay memory for each channel and at least one LFO set to sine mode. The output of the LFO can be thought of as a 13 bit integer part that specifies address offset (LFOA) and a 7 bit fractional part (LFOK) that is the coefficient used to interpolate between adjacent memory locations. The interpolation is mandatory for smooth change in delay.

The complete chorus effect requires two chorus commands. The pair of commands calculates the average of two adjacent memory locations weighted by the fractional part of the LFO (LFOK). The first chorus command is passed the middle location of the delay line and the second is passed the adjacent-to-middle location. The first command also latches in the current LFO value and complements the fractional portion (COMPK) for use in the second chorus command. The actual memory location read is the location passed plus an offset determined by the integer part of the LFO (LFOA).

chorus = value(address+LFOA)\*LFOK + value(address+1+LFOA)\*(1-LFOK)

If the LFO is set to its maximum amplitude (32767) it will add 4095 or subtract 4096 to the specified address, requiring a memory block size of 8192. Smaller modulation amplitudes (typical) can get away with a smaller memory block.

The implementation described mixes the dry signal with the chorus within the DRE, so no further mixing should be performed externally to evaluate the effect. The mixing is done internally to give the programmer complete control over predelay in order to hear its effect. In a finished implementation, the DRE is typically used only to generate the chorus, mixing is adjustable externally and predelay must take into account the different signal path delays of the dry and processed audio. Conveniently the different signal path delays often provide a good amount pre-delay on their own.

The implementation described is a Wide Stereo Chorus. Left and right channels are processed independently with independent LFOs. Starting with a stereo recording of a single voice, this will simulate two additional voices, one on each channel. A Stereo Chorus would use one LFO for both channels and starting with a stereo recording of a single voice, would create one additional stereo voice.

#### Tuning a Chorus Effect

The amount of delay modulation is proportional to the modulation depth (LFO amplitude): however, the amount of pitch modulation is proportional to the product of modulation depth and modulation rate (LFO frequency). So as you increase the LFO amplitude for a stronger effect, you may have to reduce the LFO frequency to avoid obvious warbling.

The mix of the chorus to the dry signal results in a time-varying comb-filter cancellation effect. If the predelay is too short, the comb-filter cancellation artifacts will become audible and objectionable. If the predelay is too large, the chorus will sound objectionably out of sync with the dry signal.

Modulation rate, modulation depth and predelay of the chorus relative to dry signal all contribute to sound quality. Beyond tuning these basic parameters, typical enhancements for more natural sounding chorus include adding a high-pass filter to the chorus to prevent lowfrequency beating against the dry signal, and adding a low-pass filter to the chorus to prevent strident high-frequency interference with the dry signal.

## Source Code

```
AN320103.ASM
; File:
; Description: Wide Stereo Chorus Example
            Jeff Rothermel
; Authors:
; Copyright 2001 Wavefront Semiconductor
AMP=10000 FREQ=2; f = FREQ * 0.029Hz for Fs=48kHz
LFO0
     SIN
LF01
                       FREQ=3
     SIN
           AMP=10000
MEM
     chorusmeml
                 8192
                             ; 8192 big enough for full AMP LFO
MEM
                8192
     chorusmemr
                             ; right chorus memory
; NOTE: memory locations are referenced by:
     name Start of memory block
     name' End of memory block
;
     name" Middle of memory block
RZP
      ADCL
                K=.5
                            ; Read left/2 into accumulator
WZP
                            ; Write acc to start left chorus mem
      chorusmeml
RZPB
      chorusmem1+400
                            ; Read delayed left to B reg
CHRO RZP chorusmeml" COMPK LATCH ; Read middle of chorus memory
CHR0 RAP chorusmeml"+1
                             ; Read middle+1 chorus memory
WBP
      OUTL
                 K = .999
                             ; Write dry (B) + chorus (acc) to OUTL
RZP
      ADCR
                WZP
      chorusmemr
                             ; Write acc to start right chorus mem
RZPB
      chorusmemr+400
                             ; Read delayed right to B reg
CHR1 RZP chorusmemr" COMPK LATCH ; Read middle of chorus memory
CHR1 RAP chorusmemr"+1
                             ; Read middle+1 chorus memory
WBP
      OUTR
                K = .999
                             ; Write dry (B) + chorus (acc) to OUTR
RZP
     0.0 \times 0.0
                             ;Add 16 extra reads for refresh
RZP
RZP
     0x80
RZP
     0xc0
RZP
     0 \times 100
RZP
     0x140
RZP
     0x180
RZP
     0x1c0
RZP
     0 \times 200
RZP
     0x240
RZP
      0x280
RZP
     0x2c0
RZP
      0x300
RZP
     0x340
RZP
     0x380
RZP
      0x3c0
```



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