Técnicas clássicas de distorção para síntese de sinais musicais

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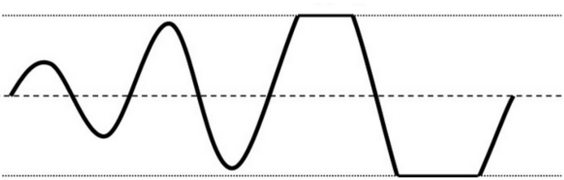
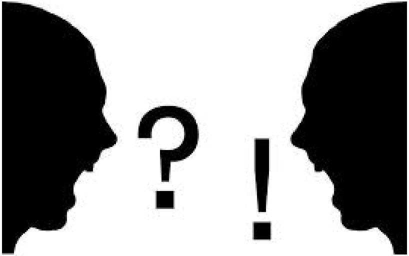
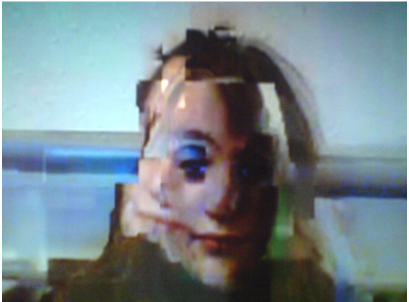
Grupo de Pesquisa em Computação Musical - IME/USP

Seminários CompMus - 2014/06/03







Distorção: *s.f.*

1 mudança de forma, de aspecto

2 alteração de sentido

Dicionário Houaiss

▷ senóide

- Desafio de encontrar sons que pareçam naturais
- Virtual Analog Oscillators - quebrar preconceito
- Distância da realidade, descoberta de novos timbres
- Baixo custo computacional e de memória
- Smartphones, RaspberryPi, Internet, etc

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"When I first got some - I won't call it music - sounds out of a computer in 1957, they were pretty horrible. (...) Almost all the sequence of samples - the sounds that you produce with a digital process - are either uninteresting, or disagreeable, or downright painful and dangerous. **It's very hard to find beautiful timbres.**"

Max Mathews, 2010.

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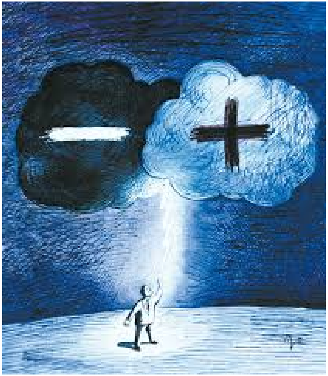
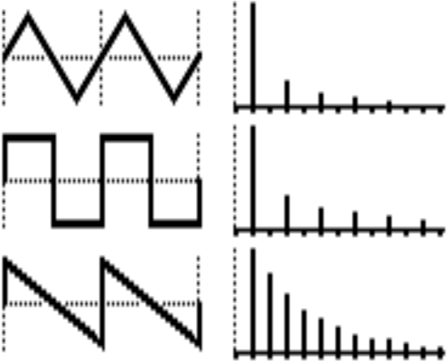
- Utilizar timbres em composições e improvisos
- Convidar compositores a testarem novos sons

Harm	Nota	Freq (Hz)	Harm	Nota	Freq (Hz)
1	$C2$	131	9	$D5$	1179
2	$C3$	262	10	$E5$	1310
3	$G3$	393	11	$F\sharp 5$	1441
4	$C4$	524	12	$G5$	1572
5	$E4$	655	13	$A5$	1703
6	$G4$	786	14	$B\flat 5$	1834
7	$B\flat 4$	917	15	$B5$	1965
8	$C5$	1048	16	$C6$	2096





▷ bell-additive

▷ waveforms

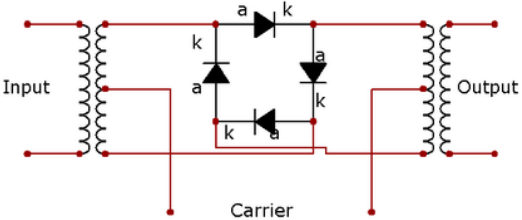
Modulação: alteração de algum parâmetro de um sinal a partir de outro sinal ou retroalimentação

- Amplitude
- Frequência
- Fase

AM e FM $\rightarrow$ rádio

- Portadora (carrier)
- Moduladora (modulator)

Modulação em anel



$$y_{RM}(n) = x_c(n)x_m(n)$$

$$\cos x \cos y = \frac{1}{2}\cos(x+y) + \frac{1}{2}\cos(x-y)$$

▷ ringmod.ck

Modulação de amplitude clássica

Aplica-se offset na portadora

$$y_{AM}(n) = (m.\alpha.x_m(n) + \alpha)x_c(n), \quad \alpha \neq 0$$

$$y_{AM}(n) = m.\alpha.x_m(n)x_c(n) + \alpha.x_c(n)$$

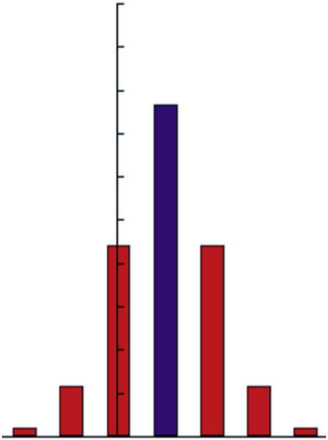
▷ am-classic.ck

Yamaha-DX7


Scanned by retrosynthads.blogspot.com
THE PERFORMANCE IS ABOUT TO BEGIN.
"Yamaha synthesizers are the only ones I've ever played and they are the only synthesizers I ever will play." ELTON JOHN
Introducing the DX FM digital synthesizers. The FM stands for the future of music. The DX means programmable and affordable performance.
What do we mean by FM digital? How user programmable? And for that matter, how affordable?
The last question is the easiest to answer. (And possibly has the most astounding answer.) $1995* for the DX7, $1395* for the DX9. For any of you familiar with FM digital, those prices have probably prompted you to split for your local Yamaha dealer already, so goodbye, this ad is over for you.
For those still hanging around to find out more, here goes: Briefly, FM digital synthesis is a totally different way of creating voices. As far from analog as a computer is
from an abacus. And totally unique from all other types of digital synthesis in that it is user-friendly and user-affordable.
Instead of VCOs, VCAs and VCFs, the DX uses
"Yamaha FM digital keyboards put new technology into the hands of musicians, yet take traditional keyboard technique into consideration. They are the next necessary step in synthesizers." DAVID PAICH/ STEVE PORCARO
"operators" to generate sound. An operator is basically a digital sine wave generator that can be used alone or in combination with other operators. Depending on the combination chosen (the algorithm), one operator can act as a carrier, the other as a modulator – much the same as in FM (Frequency Modulation) radio transmission where one frequency (an audio signal) is used to modulate another frequency (a very high frequency carrier wave).
So instead of starting with complex waveforms and cutting out harmonics as in analog synthesis, FM digital synthesis mathematically combines digitally represented sine waves to create various harmonic structures that recreate the rich harmonic content of musical sounds. These waveforms are dynamic, giving you moment-to-moment control over the
"Yamaha FM digital technology boils down to letting me capture the mood I'm after without having to think about it. Feel it and it's there." QUINCY JONES
harmonic structure of a sound. And therein, in its simplest form, lies the incredible accuracy of the DX synthesizers.
Now about programmability. Both DX models come with preset sounds so you can start playing right away. Or edit those sounds any way you like, any time you like.
"Yamaha's digital keyboards represent a breakthrough because of the rich tonal quality and responsive keyboard action." CHICK COREA
"I find Yamaha FM digital synthesizers have great warmth and color that doesn't get lost in the tracks. The sound 'speaks' the melody without sounding like a thin toy organ. All the harmonics ring true." MICHAEL McDONALD
You can also, any time you like, create any sound you like. But to do so, you must reorder
your approach to programming. Using the data entry controls and the liquid crystal display, you assign digital values to the timbre and performance parameters that go into making up the sound you wish to create.
If it sounds simple, once you get used to it, it really is.
So what else is there to say about the DX? There's a velocity-sensitive keyboard with after-touch response in the DX7. 16-note polyphonic capability in both the DX7 and the DX9. 32 voice memories in the DX7, 20 in the DX9. Computer interface and MIDI (Musical Instrument Digital Interface) capabilities for both, even breath control capability for both. And more, lots more. Let the performance begin.
For more information and
a demonstration recording write: Yamaha Combo Products, Box 6600, Buena Park, CA 90622. In Canada, Yamaha Canada Music Ltd., 135 Milner Ave., Scarborough, Ont. M1S 3R1.
"Yamaha digital keyboards have opened a new world of sound with colors I could imagine, but not express musically." JERRY GOLDSMITH
YAMAHA DX7
YAMAHA

$$y_{FM} = \sin(\theta_c + d \sin \theta_m), \quad \theta_c = 2\pi f_c, \quad \theta_m = 2\pi f_m$$

$$y_{FM} = J_0(I)\sin\theta_c + \sum_{k=1}^{\infty} J_k(I)[\sin(\theta_c + k\theta_m) + (-1)^k \sin(\theta_c - k\theta_m)]$$

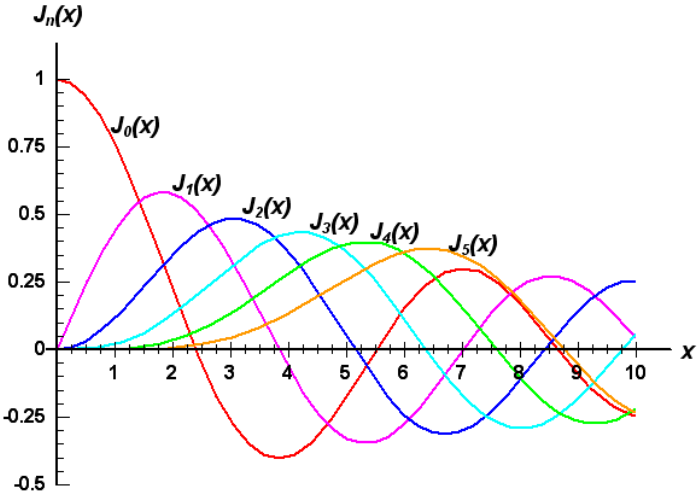


$$\begin{aligned} &= J_0(I)\sin\theta_c \\ &+J_1(I)[\sin(\theta_c + \theta_m) - \sin(\theta_c - \theta_m)] \\ &+J_2(I)[\sin(\theta_c + 2\theta_m) + \sin(\theta_c - 2\theta_m)] \\ &+J_3(I)[\sin(\theta_c + 3\theta_m) - \sin(\theta_c - 3\theta_m)] \\ &+ \ldots \end{aligned}$$

▷ fm-simple.ck

$J_k(I)$ é a função de Bessel do primeiro tipo, de ordem k, avaliada no valor do índice de modulação $I = \frac{d}{\theta_m}$

▷ fm-var.ck



FM com portadora complexa

- Um sinal modulando duas portadoras distintas
- Resultante é a sobreposição de cada modulação
- Aplicação: síntese de espectro com formantes
  - característica marcante em muitos sons naturais
  - intensidade e largura de banda controlados independentemente (pela amp da portadora e pelo índice de modulação)
- Dexter Morril utilizou essa técnica em 1977 para simular sons de trompete

FM com moduladora complexa

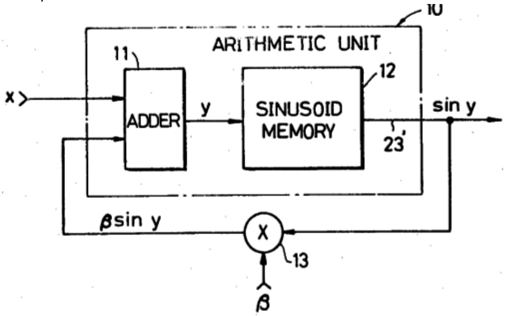
$$y(t) = A \sin(\omega_c t + I_1 \sin \omega_{m1} t + I_2 \sin \omega_{m2} t)$$

$$y(t) = \sum_{i=-\infty}^{\infty} \sum_{k=-\infty}^{\infty} J_i(I_1) J_k(I_2) \sin\left(\omega_c t + i\omega_{m1} t + k\omega_{m2} t\right)$$

- componente localizada na frequência $f_c \pm if_{m1} \pm kf_{m2}$ com amplitude $J_i(I_1)J_k(I_2)$
- Bill Schottstaedt utilizou essa técnica em 1977 para simular sons de piano e cordas em geral

FBFM - Feedback Frequency Modulation - US 4249447

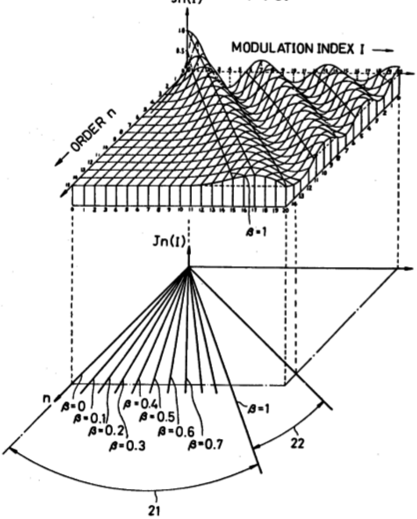
Norio Tomisawa, 1981



$$y[n] = x[n] + \beta \sin y[n-1] \rightarrow y_{FBFM} = \sin y = \sum_{n=1}^{\infty} \frac{2}{n\beta} J_n(n\beta) \sin(nx)$$

Para β próximo de 1 $\rightarrow \frac{2}{n\beta} J_n(n\beta) = \frac{2}{n} J_n(n) \approx \frac{1}{n} \rightarrow$ SAW

FIG. 4



Região das funções de Bessel aonde se concentra a FBFM.

▷ fbfm.ck

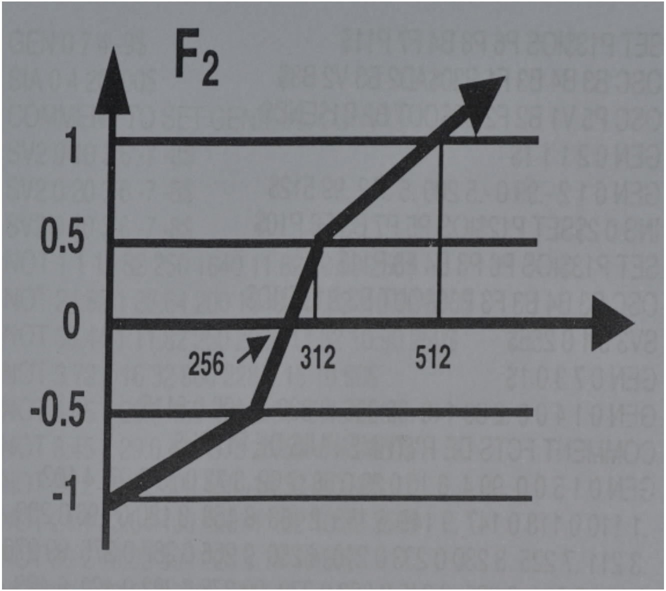
Moldar: dar forma ou contorno

Moldagem: conformação de uma substância à forma de um molde

- Processo de composição de funções
- Moldador g $\rightarrow y = g(x)$
- Distorcer deliberadamente o sinal para introduzir parciais

- Técnica proposta em 1970, por Schaefer
- "Electronic musical tone production by nonlinear waveshaping"

- Antes disso Risset já havia utilizado a técnica, para simular sons de clarinete ($\triangleright$ #150 do catalogue)
- "uma senóide submetida a uma FT não-linear", em que "a amplitude da senóide controla a quantidade de distorção aplicada a essa onda"


F2
1
0.5
0
-0.5
-1
256
312
512

Polinômios de Chebyshev

$$T_0(x) = 1$$
$$T_1(x) = x$$
$$T_2(x) = 2x^2 - 1$$
$$T_3(x) = 4x^3 - 3x$$
$$T_4(x) = 8x^4 - 8x^2 + 1$$
$$T_5(x) = 16x^5 - 20x^3 + 5x$$
$$\vdots$$
$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x)$$

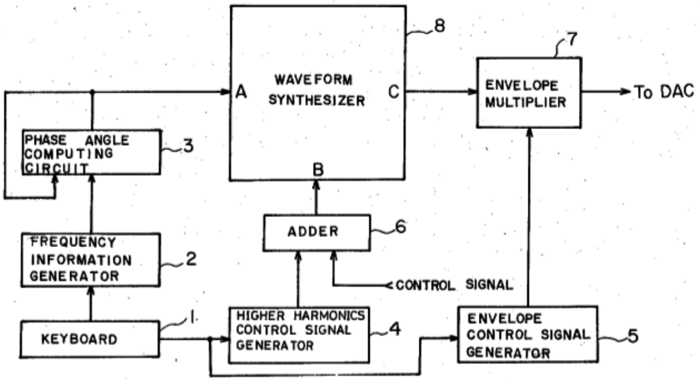
$$T_k(\cos\theta) = \cos k\theta$$

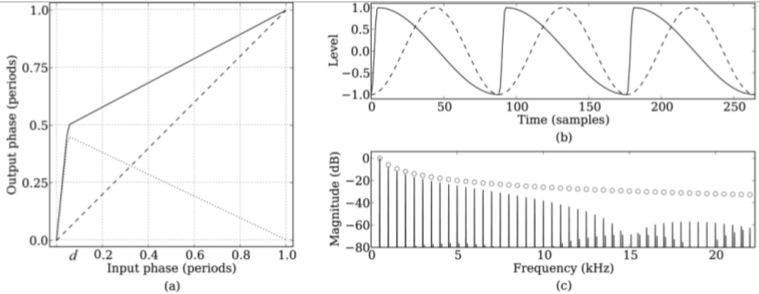
▷ waveshaping.ck


CASIO
We engineered this synthesizer so you don't have to be an engineer to play it.

Electronic music instrument - US 4658691

Masanori Ishibashi, 1987





$$P_{PD}(x) = \begin{cases} 0.5\frac{x}{d}, & 0 \leq x \leq d \\ 0.5\frac{x-d}{1-d} + 0.5, & d < x < 1 \end{cases}$$

▷ phaseshaping.ck

- Baixo custo computacional
- Elegância matemática
- Sonoridade característica

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- Técnicas abertas a modificações
  (AFM, SpSB, ModFM, FBAM, Hard Sync, VPS)

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- Retroalimentação
- Sistemas variantes

Obrigado! ag@ime.usp.br compmus.ime.usp.br