Fermi National Accelerator Laboratory

TM-1645

A Nonlinear Oscillator

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January 27, 1990

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

TM 1645
1-27-90

A Nonlinear Oscillator

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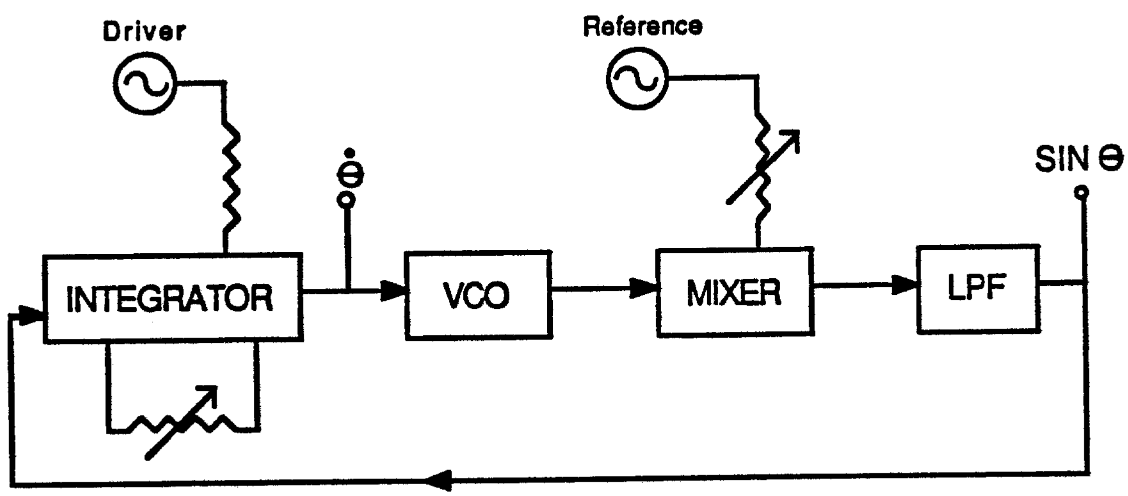
A nonlinear oscillator design was imported from Cornell, modified, and built for the purpose of simulating the chaotic states of a forced pendulum. Similar circuits have been investigated in the recent nonlinear explosion.

Circuit Funtion:
A block diagram shows the circuit which is a phase locked loop. The voltage controled oscillator output is mixed with a reference signal. The result is filtered, integrated, and fed to the VCO as the error correction signal. This VCO locks over a range of approximately 23 to 27KHz. The natural operating frequency of the circuit is approximately 25KHz and is variable with the integrator setting. The low pass filter was breadboarded separately. Its response curve is included here. A VCO input verses frequency out curve for open loop is included.



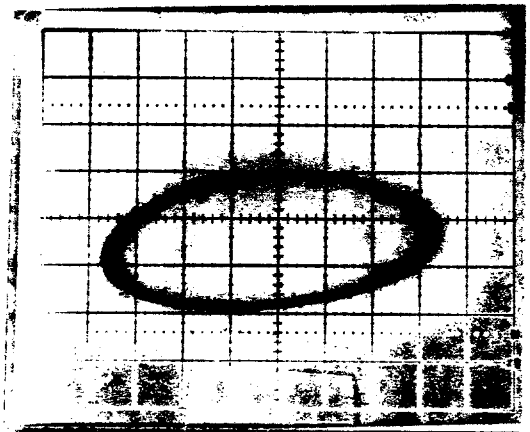
BLOCK DIAGRAM

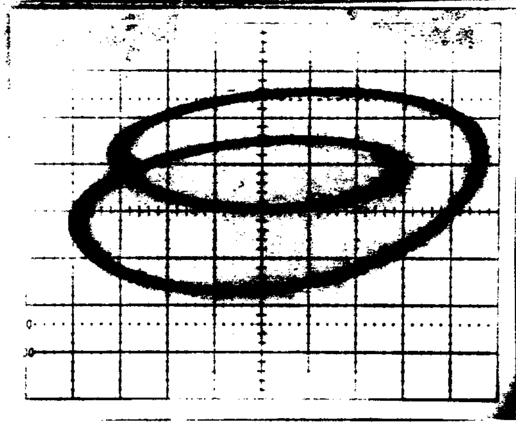
The integrator IN and SINE inputs are fed with separate signals having variable frequency, amplitude, and DC offset settings.

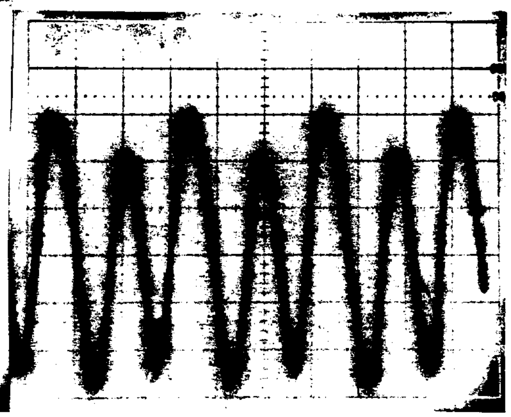
A full range of nonlinear effects can be obtained. The SIN theta and theta dot signals were plotted as X versus Y on a TEK 454A to produce the bifurcation images included here. The accompanying time traces are also shown. More spectactular and fun things can be made to happen. For example, with a speaker at the integrator output we have generated bird calls like the whip-poor-will.

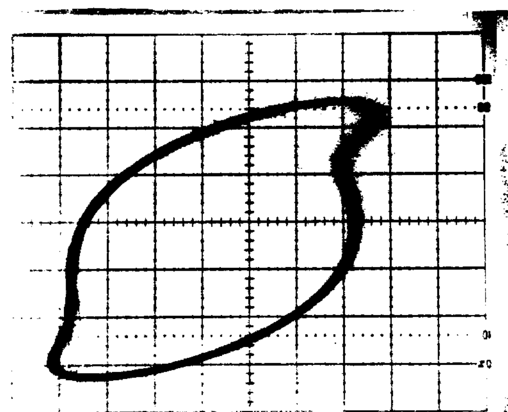
The oscillator was hooked to a TEK DSA 602 digitizing signal analyzer to plot theta dot versus SIN theta in XY fashion and simultaneously an FFT of theta dot. The fundamental frequency can be seen to go lower upon bi-furcation. DSA 602 plots show a. a stable oscillation with second harmonic 30 dB down, b. bifurcation with the third frequency appearing and the spectrum shifting down, c. the oscillator tuned back to the stable condition, d. two bifurcations with four dominant frequencies and signs of more (chaos). In figure d the spectrum also shifts even lower.

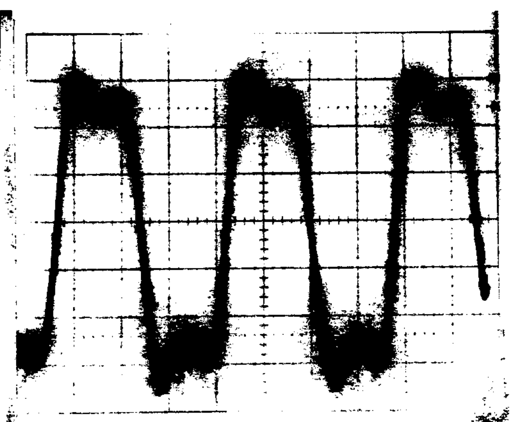
1. The circuit was obtained by private communication with Bob Siemann.
2. Chaotic States and Routes to Chaos in the Forced Pendulum. D. D'Humieres et all. Physical Review A (1982) 3483
3. Three-Frequency Quasiperiodicity, Phase Locking, and the Onset of Chaos. P. Linsay and A. Cumming. Physica D 40 (1989) 196-217

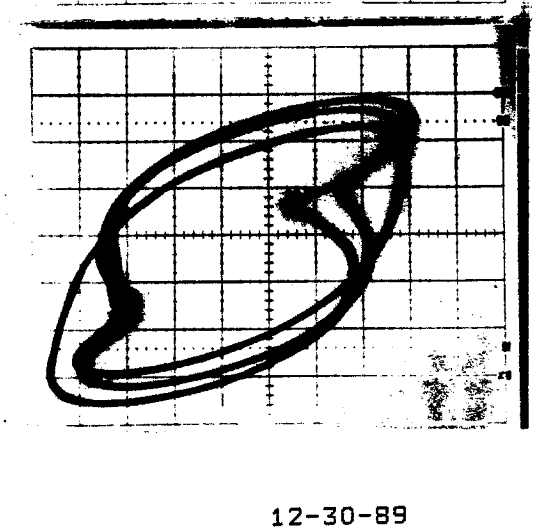












12-30-89
R. Tomlin

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 31-DEC-89 time: 10:43:23

Figure a.
"Stable", with second harmonic.

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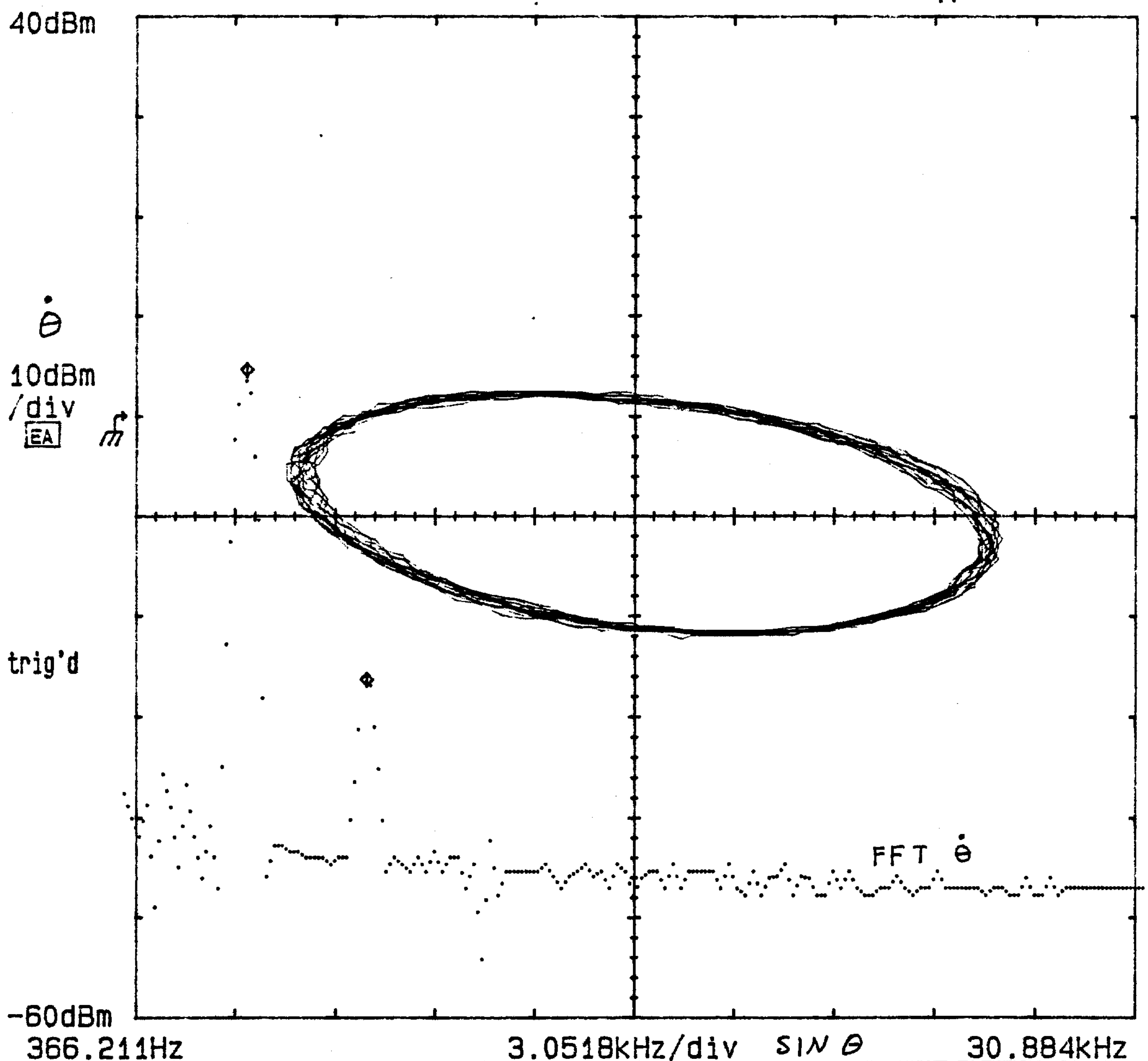

Cursor Type Paired Dots	v1= 4.672dBm v2= -26.26dBm Δv= -30.93dBm	f1= 3.662kHz f2= 7.324kHz Δf= 3.662kHz	Rem Wfm 1 FFTm Main

Cursor 1	Cursor 2
3.662kHz	7.324kHz

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 31-DEC-89 time: 10:49:04

Figure b.
Bifurcation with the third frequency appearing and spectrum shifted down.

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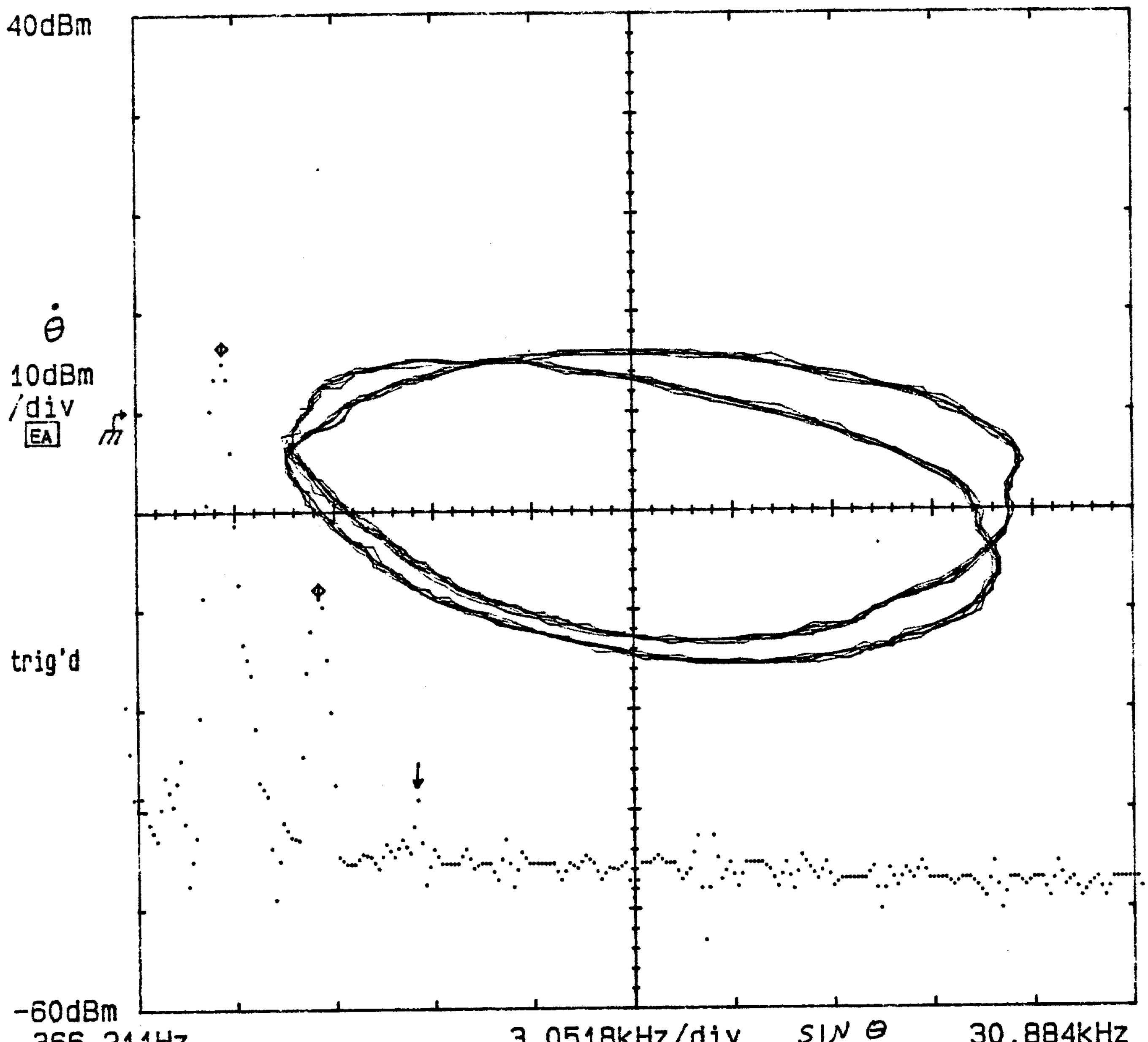

Cursor Type Paired Dots	v1= 6.438dBm	f1= 2.930kHz	Rem Wfm 1 FFTm Main
	v2= -17.98dBm	f2= 5.859kHz	
	Δv= -24.41dBm	Δf= 2.930kHz	

Cursor 1		Cursor 2
2.930kHz		5.859kHz

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 31-DEC-89 time: 10:59:02

Figure c.
Oscillator tuned back to condition a.

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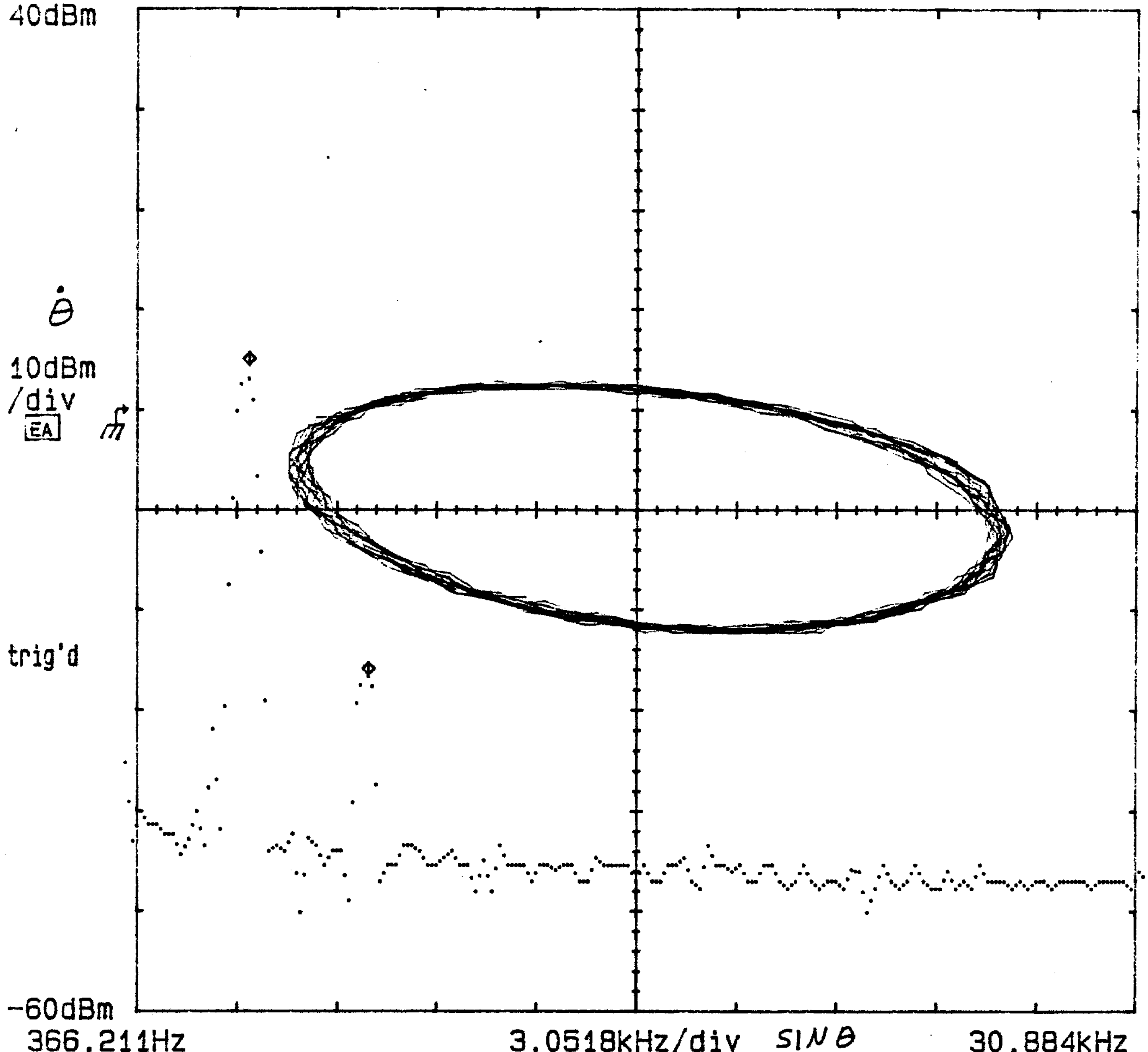
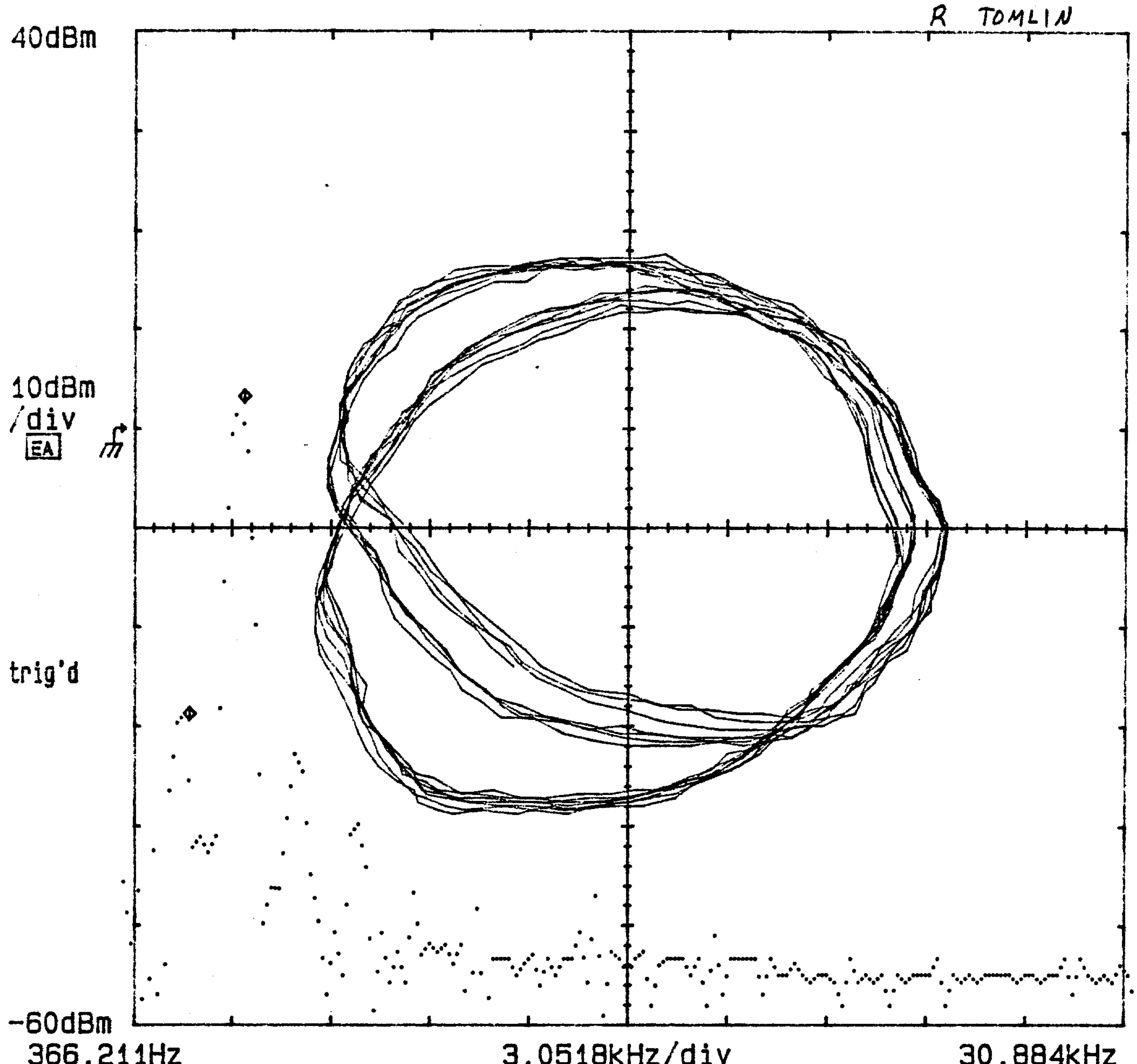


Cursor Type Paired Dots	v1= 5.125dBm	f1= 3.662kHz	Rem Wfm 1 FFTm Main
	v2= -25.81dBm	f2= 7.324kHz	
	Δv= -30.94dBm	Δf= 3.662kHz	

Cursor 1		Cursor 2
3.662kHz		7.324kHz

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 31-DEC-89 time: 11:56:54

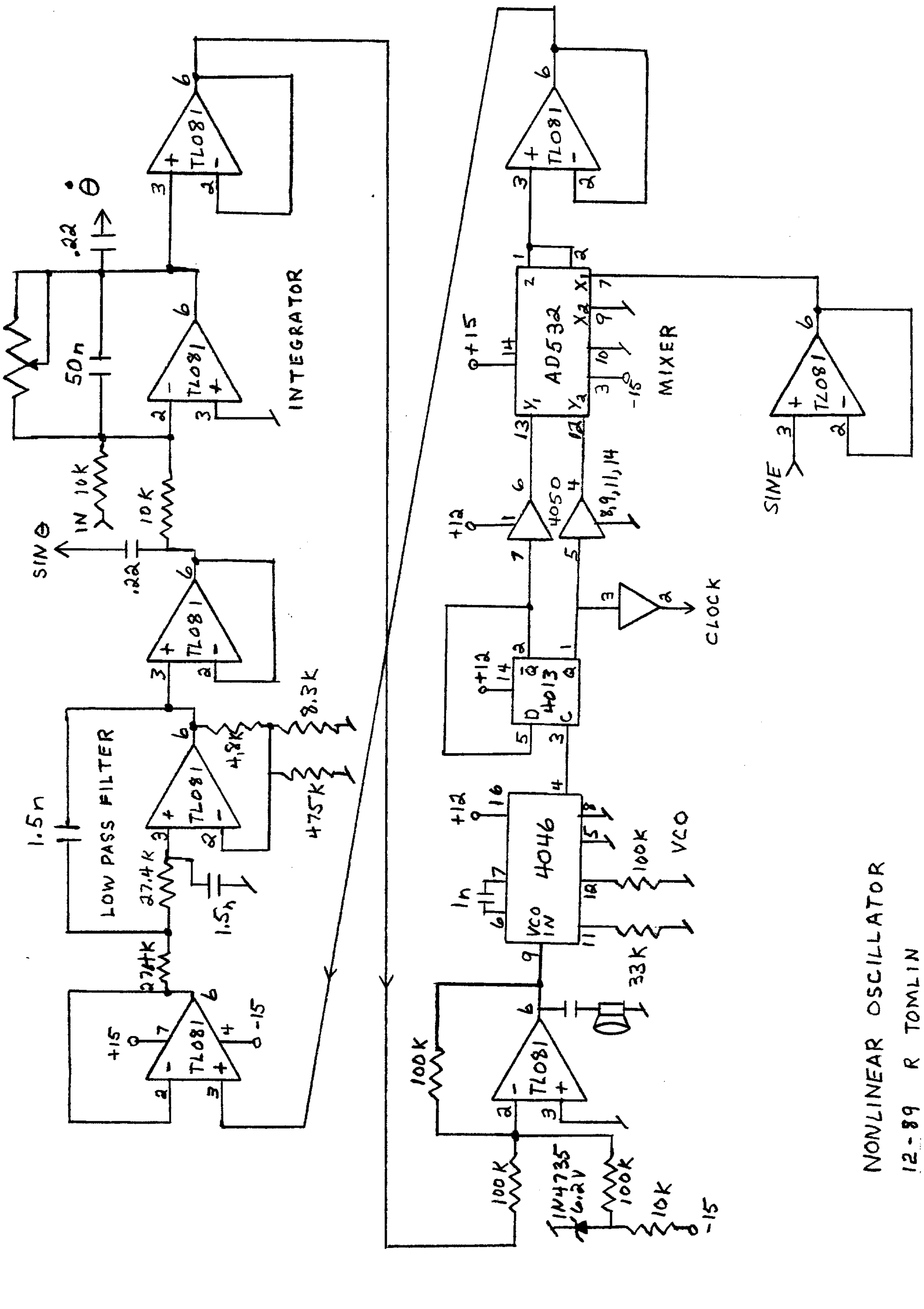
Figure d.
Two bifurcations. More frequencies appear.



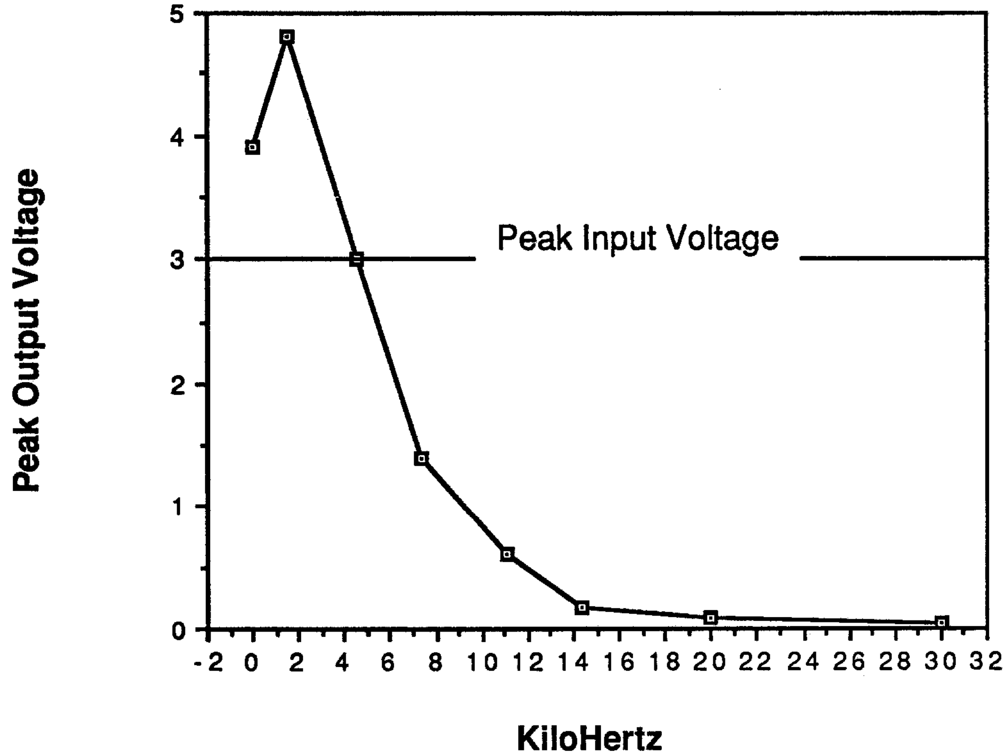
Cursor Type Paired Dots	v1= 3.219dBm	f1= 3.662kHz	Rem Wfm 1 FFTm Main
	v2= -28.77dBm	f2= 1.953kHz	
	Δv= -31.99dBm	Δf=-1.709kHz	

f3 = 5.371
f4 = 7.324
f5 = 9.033
f6 = 10.99
f7 = 14.65
f8 = 18.31

Cursor 1		Cursor 2
3.662kHz		1.953kHz


NONLINEAR OSCILLATOR
12-89 R TOMLIN
INTEGRATOR
LOW PASS FILTER
MIXER
VCO
CLOCK
SIN θ
θ̇
SINE
IN 10K
TL081
AD532
4046
4013
4050
1N4735 6.2V
10K
50n
.22
1.5n
27.4K
4.8K
8.3K
475K
100K
33K
1n
+15
-15
+12

Low Pass Filter Response



VCO Transfer Function

y = 9.3301 + 0.6989x + 0.3112x^2 - 0.018x^3   R = 1.00