Progress Report on the Development of the FM-type Musical Instrument for the Period of January 1975 to April 1976

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Objectives in 1975 period:

1. Establish the product concept, in which the FM algorithm is advantageous over the conventional, around the types of:
   1. * Single tone synthesizer — for pedal of #2 and new tones
   2. * Muti-channel electronic organ
   3. * Entirely new electronic keyboard

   All the above will require MOS or some faster device technology.

   The first one is technically most feasible to be implemented with the established MOS because of its single channel (lesser speed).

   The second one may require the recent state of the art technology which could turn out to be less cost effective.

   For the third one, we have yet conceived no clear vision.

2. Mock up the TTL system to study the hardware architecture, optimal algorithm, and necessary parameters for the desired sounds.

3. Supplement the above with various information such as simulation results, wave form analysis of the natural tones, and so on.

Experimental systems:

In early 1975, the first TTL model was fabricated to evaluate the FM technique. It was a single tone, parallel processing, micro-program oriented system (direct copy of Stanford patent application).
Later in November 1975, it was evolved into exclusively bass-note purpose machine. Several improvements such as adoption of double precission numbers, addition of another index, etc. were carried out, but the sampling rate was reduced. 125 micro sec. as opposed to 50

In June 1975, also TTL, the multi-channel FM organ was constructed. Using logarithm conversion arithmetic, it was capable of generating twelve concurrent notes that were time multiplexed. for reduction of multiplication problem
This was the first type of complete electronic organ and had two manuals and one pedal keyboard. 12 microseconds sampling

In late 1975, the first 100% MOS oriented serial processing system was designed and the bread-board model is now being fabricated.
Here, the SIN table was removed from the system.
Instead, the SIN curve was approximated by the quadratic function, in which we could neglect about 3% of over-tone distortion.
Technically, this system can be realized with the proven MOS technology. but, only justified by quality and novelty of tones, beyond current organ technology

Since the fourth quarter of 1975, another multi-voice, multi channel system has been developed.

This is the fast, powerful experimental model to explore the capability of FM technique to the extreme.
In the system, the wave calculation algorithm can be altered at real time by loading different micro-programs from its control element, Intel's 3000.
If typical FM algorithm (three indices with one carrier plus one index with one carrier) was chosen, it would generate forty concurrent notes.
It also can be hooked to the computer simulation program, so that tone data, micro instructions, key detection and channel assignment programs are flexiblly manipulated via host computer to enable us more versatile experiment.
Because of its speed, 250 ns, it would require faster technology than current MOS if it was to be realized.

Experimental System Spec.

Project	M1	M0	M3	M2	GOSSIP
Purpose	FM evaluation	FM evaluation, Product survey	MOS implementation	Product survey, parameter search	Parameter search, data entry
Clock	5 MHz (4 phase)	1 MHz	1 MHz	4 MHz	PDP-11 GT-40
Data format	16 bits (later, 32 bits) parallel	8 bits parallel	16 bits serial	16 bits parallel	Graphics Oriented Sound SImulation Program Function: *Data entry *Wave computation *Single tone play-back *Bessel analysis *Data conversion & feed it to M1,M2,M3
Data domain	linear	log	linear	linear	
SIN	table look-up, interpolation	table look-up	quadratic approximation	table look-up, interpolation	
Control	micro instruction, bus	wired	wired	micro instruction, ptly wired	
# of channels (voices)	1	12	1	40 (typical)	
# of ~~voices~~ timbres	8	20	8	over 60	
Data storage, entry	ROM, RAM from GOSSIP	ROM, console	ROM, RAM from GOSSIP	ROM, RAM from GOSSIP	
Sampling rate	50 micro sec. (later 125)	12 micro sec.	32 micro sec.	16 micro sec.	
FM equation	(1)	(2)	(3)	(4)	
Performance availability	now	now	-	now (10 channels)	

Equations for the experimental systems:

$$e(t) = A(t)\,\mathrm{SIN}\left[\omega_c t + \varphi_c + (I_1(t) + A_v\,\mathrm{SIN}\,\omega_v t)\,\mathrm{SIN}(\omega_1 t + \varphi_1) + I_2(t)\,\mathrm{SIN}(\omega_2 t + \varphi_2)\right] + B(t)\,\mathrm{SIN}\left[\omega_B t + \varphi_B + I_3(t)\,\mathrm{SIN}(\omega_3 t + \varphi_3)\right] \quad \ldots (1)$$

$$e(t) = A(t)\,\mathrm{SIN}\left[n_1 \omega_c t + I_1(t)\,\mathrm{SIN}\,(n_2 + \Delta n_2)\,\omega_c t + I_2(t)\,\mathrm{SIN}\,n_3 \omega_c t\right] + B(t)\,\mathrm{SIN}\,\omega_c t \quad \ldots (2)$$

$$n_1, n_2, n_3 = 1, 2, 3, \cdots, 9$$

$$e(t) = A(t)\,\mathrm{SIN}\left[\alpha(t)\,\omega_c t + I_1(t)\,\mathrm{SIN}\{\alpha(t)\cdot\beta(t)\cdot\omega_1 t\} + I_2(t)\,\mathrm{SIN}\{\alpha(t)\cdot\omega_2 t\}\right] + B(t)\,\mathrm{SIN}\left[\alpha(t)\cdot\omega_B t + I_3(t)\,\mathrm{SIN}\{\alpha(t)\cdot\omega_3 t\}\right] + P(t) \quad \ldots (3)$$

$$e(t) = \sum A_N(t)\,\mathrm{SIN}\left[\omega_{cN} t + \varphi_{Nc} + \sum I_M(t)\,\mathrm{SIN}(\omega_M t + \varphi_M)\right] \quad \ldots (4)$$