1. GENERAL DESCRIPTION

AMY 1 is a digital, pipeline architectured, additive music synthesizer chip. There are 8 voices maximum assignable with a total of 64 harmonic oscillators, available in groups of two, for voice assignment. AMY 1 has 72 independent, piecewise linear envelope generators: 8 fundamental frequency envelopes and 64 harmonic amplitude envelopes. A complete sound system requires addition of a D/A converter IC (up to 16 bit). To provide higher level commands, the system will generally include a controlling processor such as the Intel 8051 single chip microcomputer.

2. FEATURES

- Single 40 pin DIP
- 3u HMOS technology
- Pipeline architecture
- 10 MHz external clock frequency (maximum)
- Integrated exponential ROM
- 1/128 dB harmonic amplitude resolution & 1/64 semitone fundamental frequency resolution
- Interrupt/Ready pin
- Bus compatible with multiplexed and non-multiplexed bus microprocessors
- Full 16 bit digital output width
- Independent voice mode
- Adjustable sample rate
- Programmable noise statistics
- 72 on chip envelope generators
- Approximately 37,000 transistors

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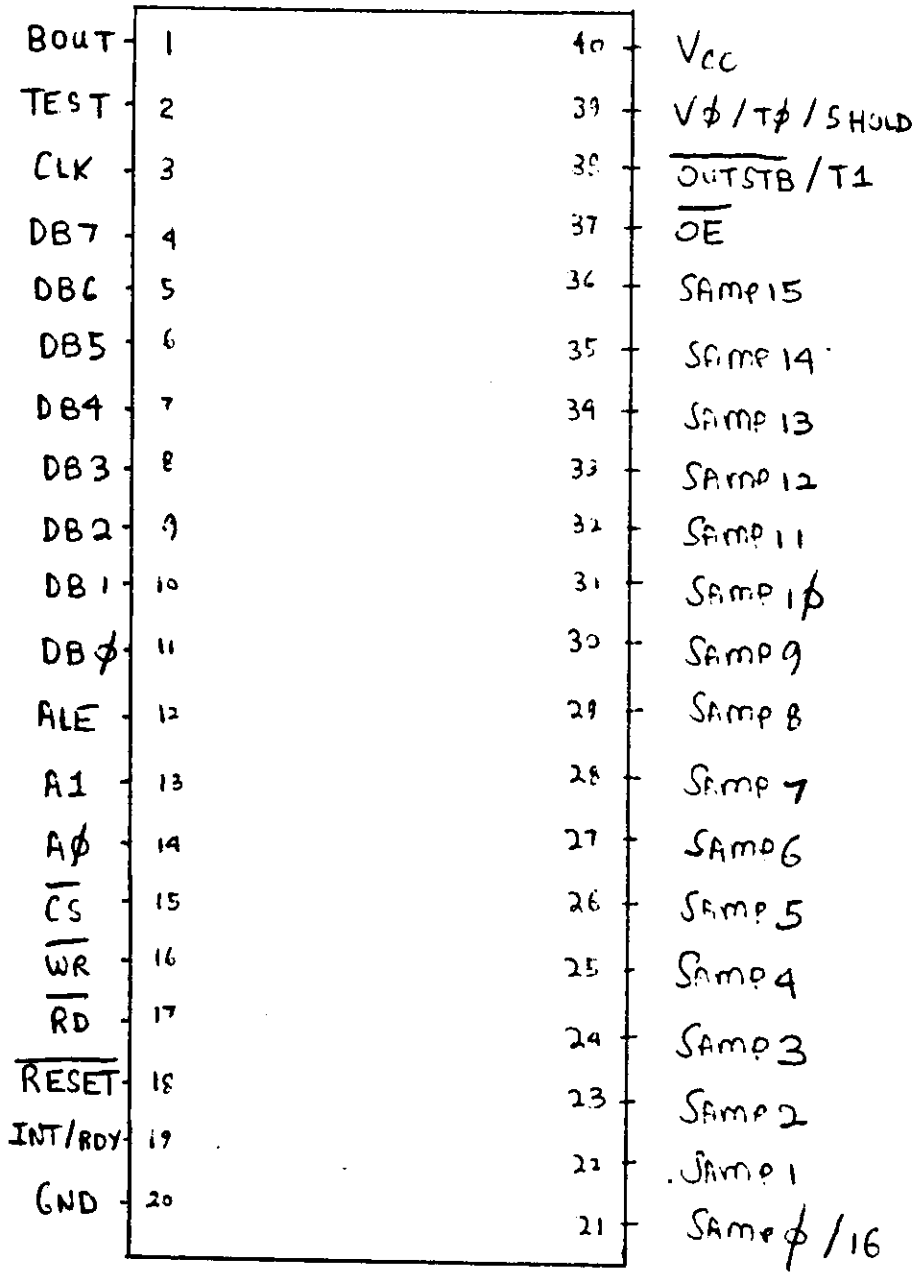
AMY PINOUT



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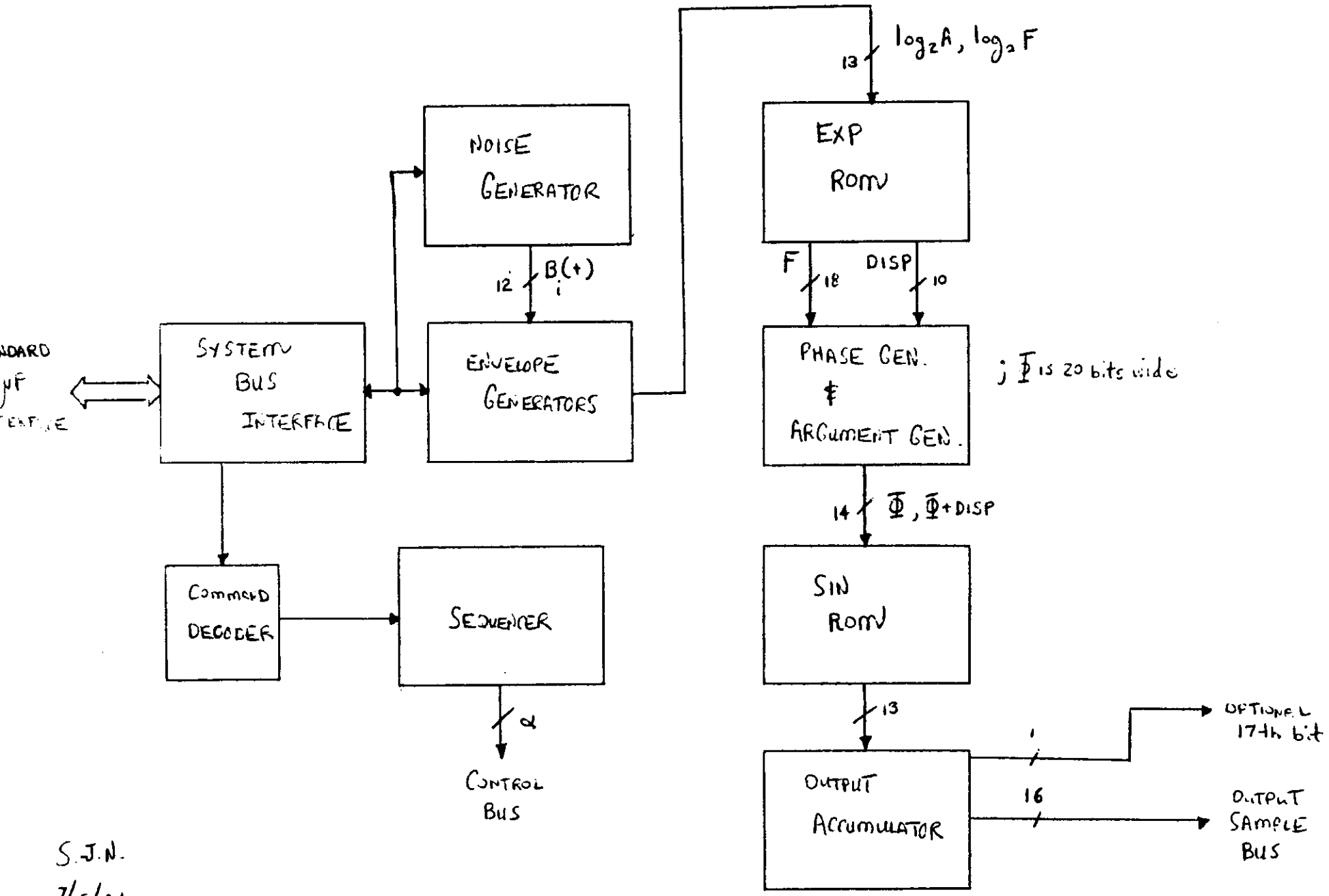
AMY BLOCK DIAGRAM (SIMPLIFIED)



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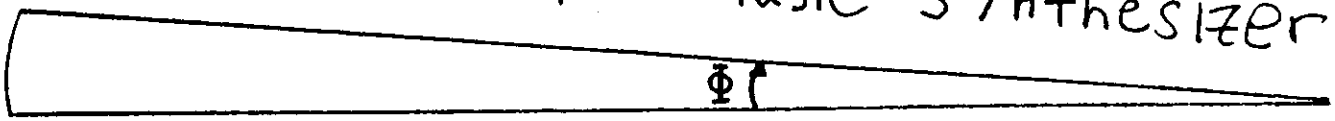
AMY 1 - Additive Music sYnthesizer



Definitions;

LH_i = LAST HARMONIC OF VOICE i (1 THRU 64). $LH_\phi = \phi$

i = VOICE NUMBER (1 THRU m).

m = NUMBER OF VOICES SYNTHESIZED (1 THRU 8).

j = HARMONIC NUMBER (1 THRU 64).

$B_i(t) = B_\phi(t)$ OR $B_1(t)$; OUTPUTS OF NOISE GENERATORS 1 & 2.- (12 b.t twoscomplement number corresponding to band limited white noise ($SINX^2$);)
OR 1.-(noise disabled; $2^{B_i(t)} - 1 = 1$)

A_j = AMPLITUCE FUNCTIONS OF TIME, ONE FOR EACH HARMONIC.

f_i = FUNDAMENTAL FREQUENCY FUNCTIONS OF TIME, ONE FOR EACH VOICE.

Φ_j = PHASE SCRAMBLE CONSTANTS (ONE FOR EACH HARMONIC)

t = time

$$SAMP = \sum_{i=1}^{m} \left[\sum_{j=LH_{(i-1)}+1}^{LH_i} \left(2^{B_i(t)} - 1\right) A_j \sin\left[(2\pi \cdot (j - LH_{(i-1)}) \cdot f_i \cdot t) + \Phi_j\right] \right]$$

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Let $m = 1$, $LH_1 = 64$

& $B_i(t) = 1$ ($i = 1$ only)

then:

Each A_j has it's own Amy envelope generator

$$SAMP = \sum_{j=1}^{64} A_j(t) \sin\left[2\pi \cdot j \cdot f_i \cdot t + \Phi_j\right]$$

$$= \sum_{j=1}^{64} A_j(t) \sin\left[2\pi \cdot j \cdot f_i(t) \cdot t + \Phi_j\right]$$

Each $f_i(t)$ has it's own Amy envelope Generator

thus: Amy 1 has

i) 64 Amplitude Envelopes
ii) 8 Frequency Envelopes

} 72 on chip generators controlled by (source, destination) command duples.

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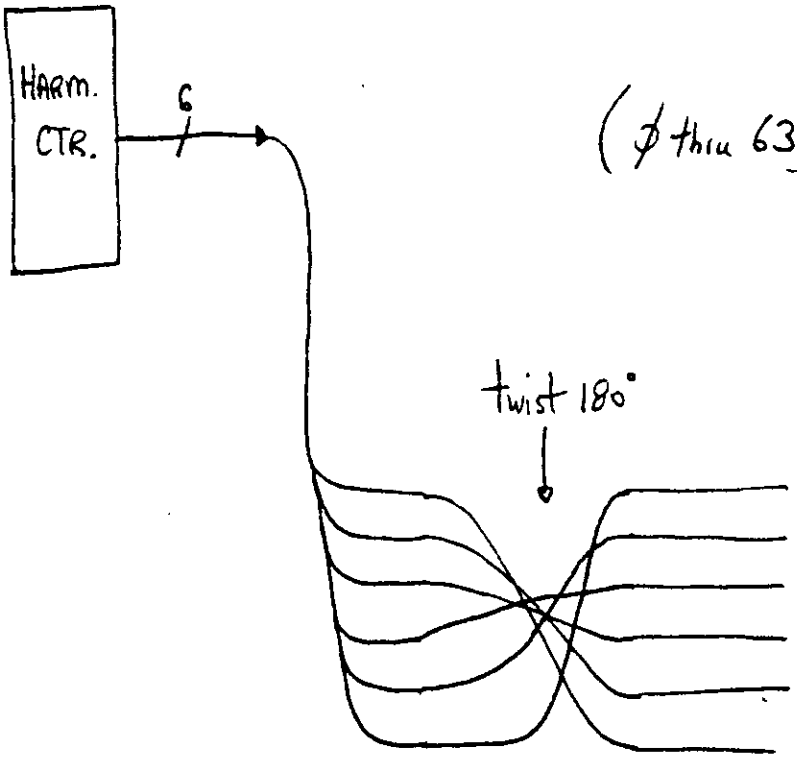
PHASE SCRAMBLER



example (first 8 HARMONIC NOISE OSCILLATORS)

HARMONIC	SCRAMBLE CONSTANT	ϕ ADDED
Hϕ	000100	22.5°
H1	100100	202.5°
H2	010100	112.5°
H3	110100	292.5°
H4	001100	67.5°
H5	101100	247.5°
H6	011100	157.5°
H7	111100	337.5°
⋮		

} PAIRS OF HARMONICS ARE 180° OUT OF PHASE WITH ONE ANOTHER.

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- the PHASE of each fundamental oscillator is saved in a 20 bit RAM location. (PHASE RAM IS 8x20 bits)

- the PHASE of All 2nd, 3rd... 64th Harmonics are computed by doubling, tripling, quadrupling, etc. the fundamental oscillator PHASE

- PHASE RAM locations are actually accumulators. Each sample period (32 μs) the current contents of the FREQUENCY RAM are added to the PHASE for all voices (all fundamentals) The FREQUENCY CURRENT VALUE is An 18 bit unsigned number.

- FREQUENCY, and HARMONIC RAM CURRENT VALUES ARE CHANGING EITHER EVERY 2, 8, 32, or 128 SAMPLE PERIODS. (SLOPE BYTE bits 6,5) THIS IS THE FUNCTION OF THE 72 ON CHIP ENVELOPE GENERATORS!

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to avoid the two required multiply's per Harmonic (128 per sample period)
A number of tricks were combined, they capitalize on the
on chip exponential Rom.

$$2^{B_i(t)+A_j} - 2^{A_j}$$

$$= 2^{B_i(t)} \cdot 2^{A_j} - 2^{A_j}$$

$$= 2^{A_j} \cdot (2^{B_i(t)} - 1)$$

but since $A_j = 2^{\log_2 A_j} = A_j$

We pass on successive clock cycles to the exponential Rom input

$\log_2 A_j$ (Amplitude in db)

& $B_i(t)$ (our noise generator output) + $\log_2 A_j$

they are differenced After they are exponentiated

$$2^{[\log_2 A_j + B_i(t)]} - 2^{\log_2 A_j} = A_j (2^{B_i(t)} - 1) = \text{DISP}$$

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– first multiply of n

the second multiply is eliminated by implementing A well known TRIG identity;

$$\sin\alpha - \sin\beta = 2\cdot\cos[\tfrac{1}{2}(\alpha+\beta)]\cdot\sin[\tfrac{1}{2}(\alpha-\beta)]$$

Letting $\alpha = PH + DISP$

$\beta = PH$; PH = PHASE (most significant 14 bits of 20bit "PHASE RATIO CURRENT VALUE")

We get

$$\sin(PH+DISP) - \sin(PH) = 2\cdot\cos[PH + DISP/2]\cdot\sin[DISP/2]$$

but $\sin[DISP/2] \simeq DISP/2$ for $DISP \ll 2\pi$

note 1 [for $DISP = \pi/8$ there is a 0.65% gain error.]

Substituting we get

$$\sin(PH+DISP) - \sin(PH) = DISP\cdot\cos[PH + DISP/2]$$

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So by passing PH & PH + DISP = $PH + A_j(2^{B_i(t)} - 1)$ to the input of the SIN Rom and differencing these outputs from the SIN Rom we get

$$\sin(PH + DISP) - \sin(PH)$$

which we know

$$= DISP \cdot \cos[PH + DISP/2]$$

$$= A_j(2^{B_i(t)} - 1)\cos[PH + PH_{error}]$$

which asside from the PHASE ERROR (PH_{error}) is what we want

the maximum PH_{error} is = 1.1% of 2π, And is inaudible (to us!)

ignoring the PHASE ERROR we get

$$f(t) = A_j(2^{B_i(t)} - 1) \cdot \cos[PH]$$

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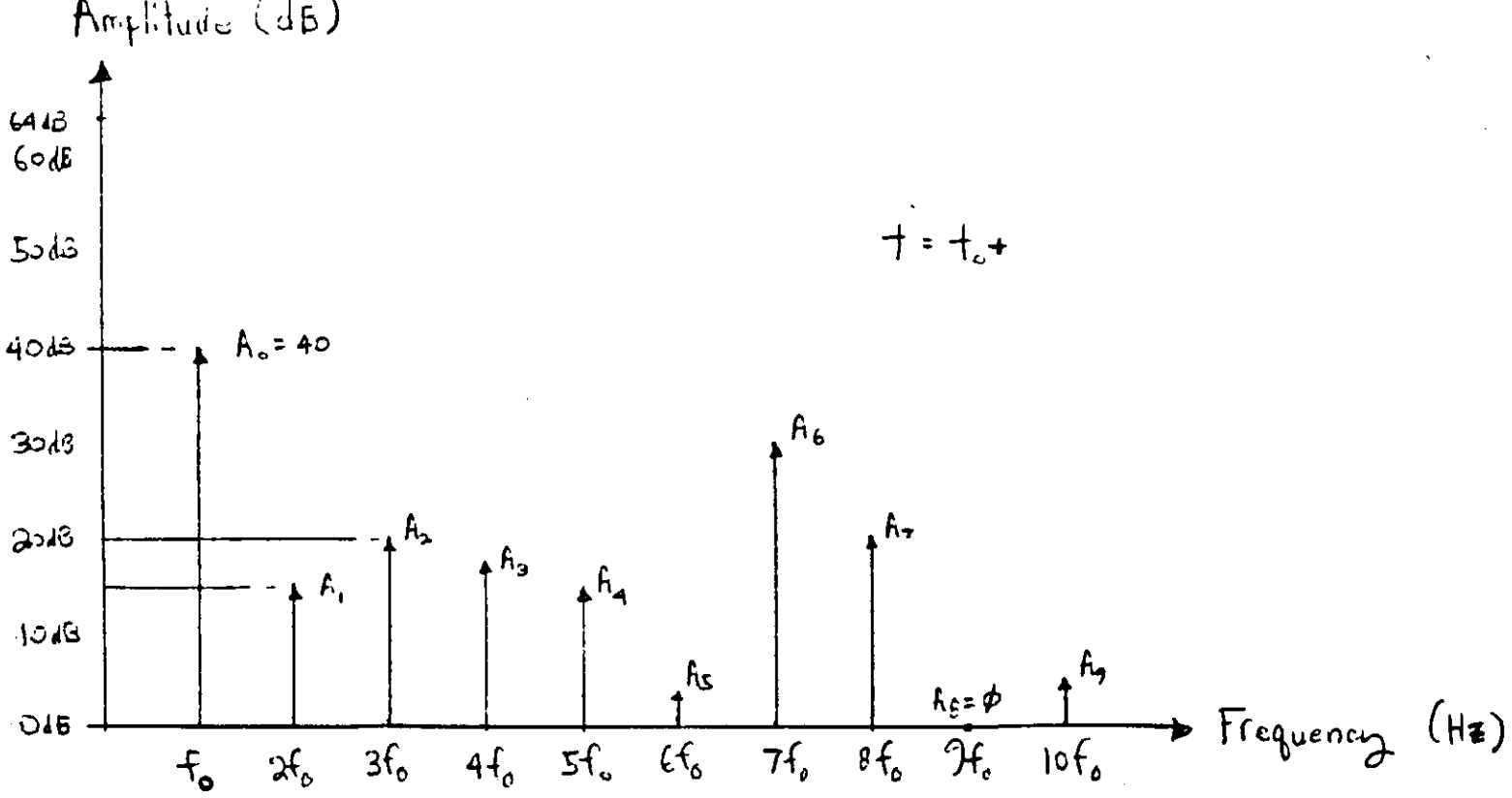
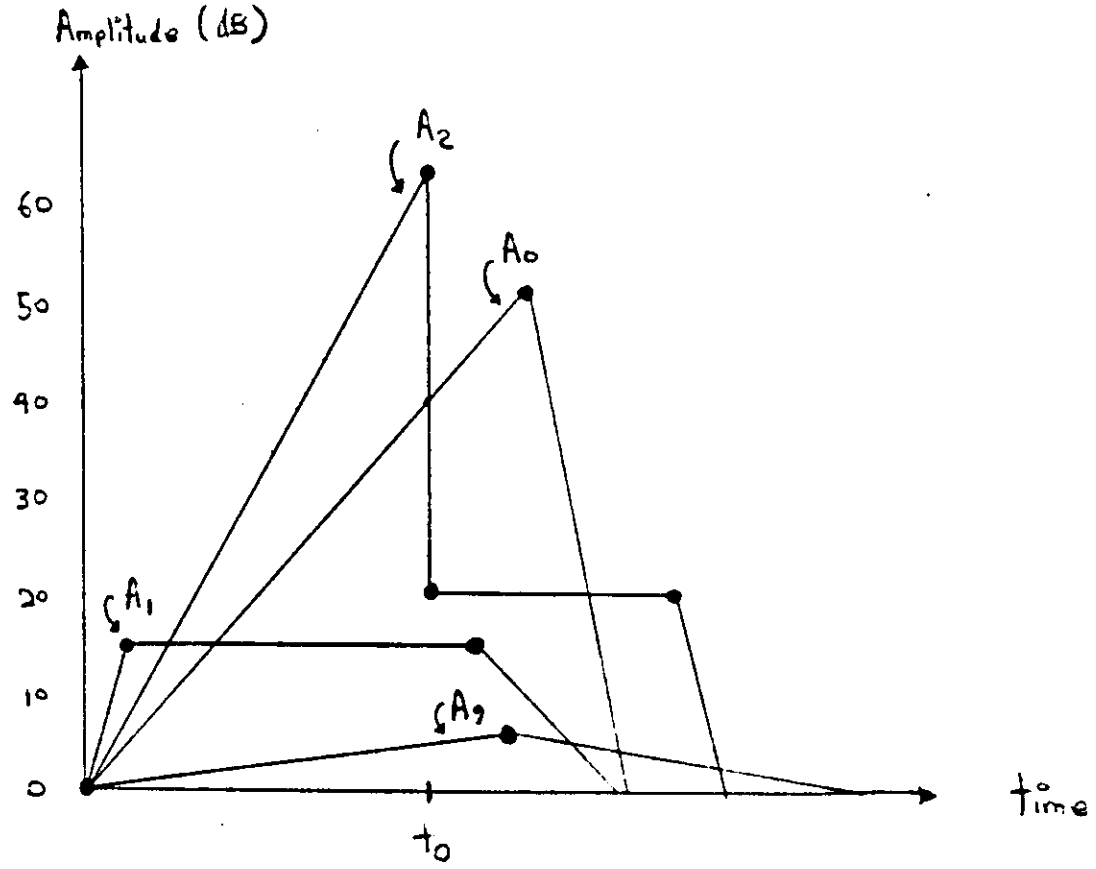
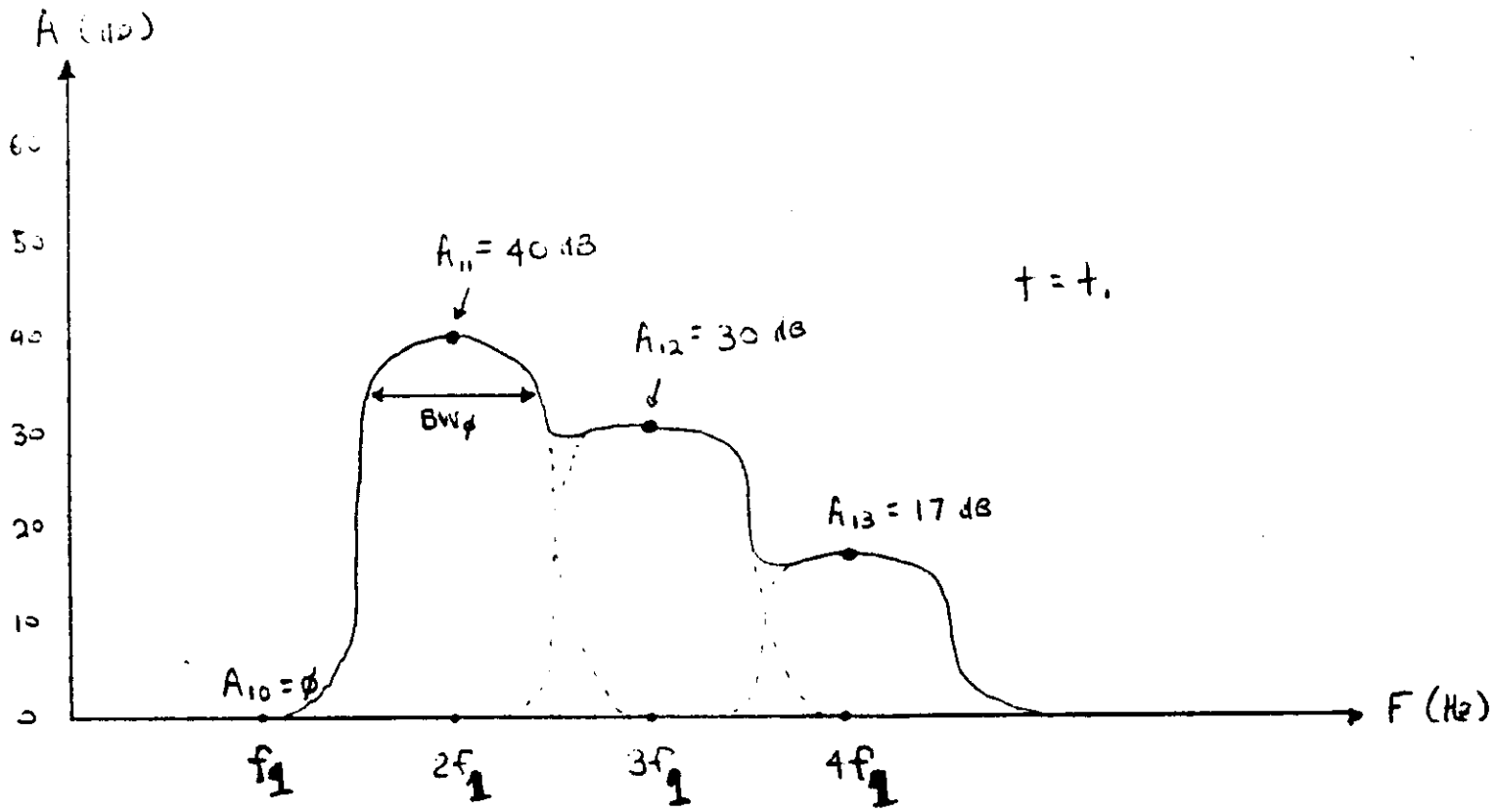
$B_i(t)$ is held at 1 when noise is disabled so;

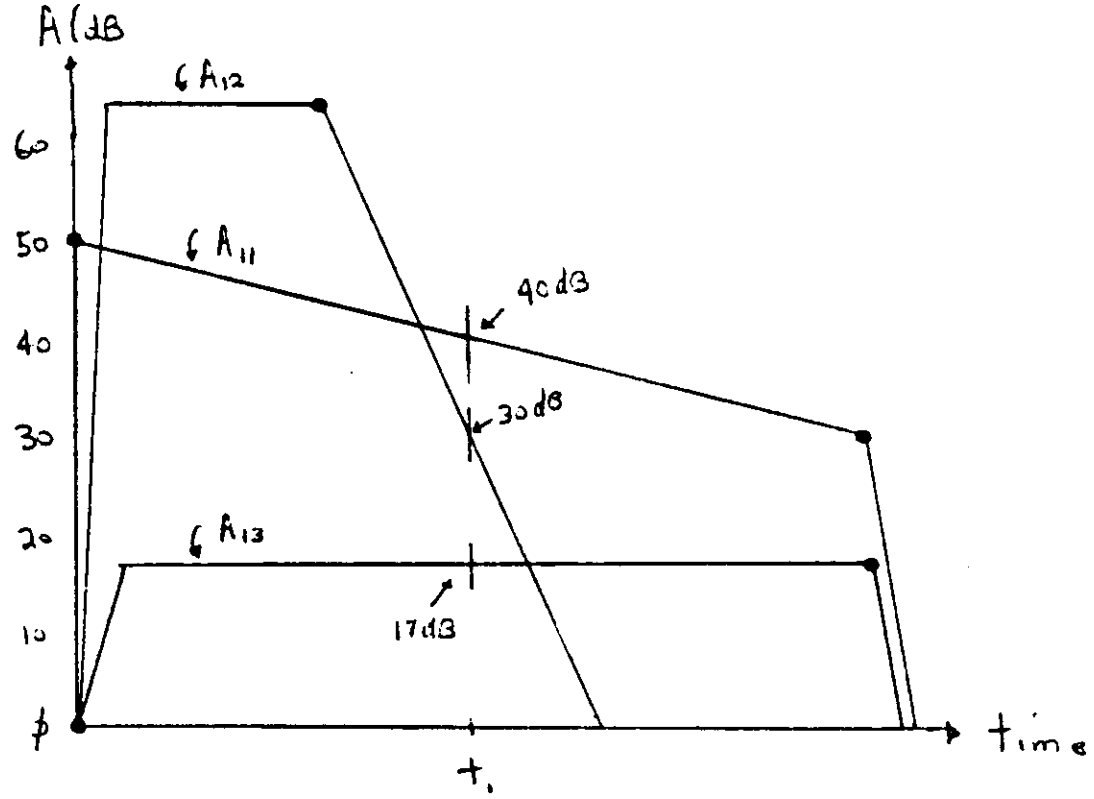
$$f(t) = A_j \sin[PH + \pi/2]$$





AMY - HARMONIC VOICE





AMY - NOISE BASED VOICE (Noise Generator ϕ)

Musical Specifications

Given an internal CLK frequency of 8 MHz with 64 Harmonics enabled:

Amplitude Dynamic Range	63.75 dB
Minimum Amplitude Slope	1.91 dB/sec
Maximum Amplitude Slope	3784 dB/sec (16.9 msec to full scale (13.5 msec
Fundamental Frequency Range	4.8 Hz to 7.8 KHz (10 2/3 octave range)
Minimum Fundamental Frequency Slope	5.97 cents*/sec
Maximum Fundamental Frequency Slope	118 semitones/sec = 9.85 octaves/SECOND
Maximum Amplitude Increment	31/128 = 0.242 dB
Fundamental Frequency Increment	1/64 semitones = 1.56 ¢ (cents ≡ ¢)
Fundamental Frequency Destination Resolution	1/64 semitones = 1.56 ¢
Harmonic Amplitude Destination Resolution	1/4 dB
Number of Harmonics	64 (maximum)
Number of Voices	8 (maximum)
Number of Harmonics/Voice	Any multiple of 2
Harmonic Distortion	< 1%

* 1 cent = 1/100 of a semitone

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A M Y μP I N T E R F A C E

- STANDARD 8-BIT BUS (ASYNCHRONOUS)
- ALE OR ADDRESS PIN MODE SELECTABLE IN S/W
- ACCEPTS WIDE VARIETY OF CONTROLLING PROCESSORS
- AVERAGE COMMAND EXECUTION TIME = 3.2 μSEC
- MAXIMUM REGISTER READ/WRITE DATA RATE = 3.3 Mbytes/SEC

7. REGISTER ORGANIZATION

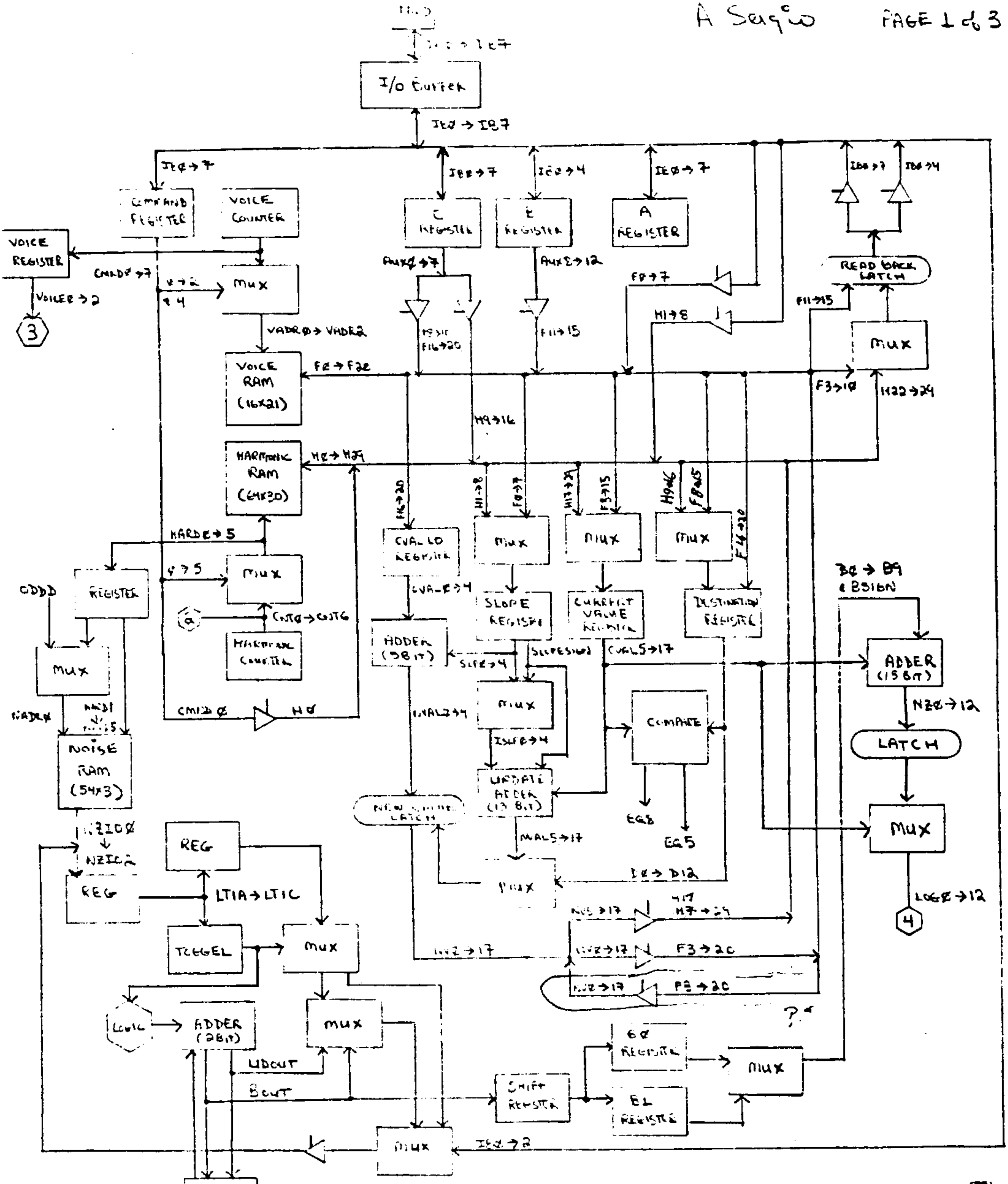
7.1 AMY 1 Command Set

A command may be sent to AMY 1 by setting $\overline{CS}$ = A1 = AØ = 0, $\overline{RD}$ = 1 and $\overline{WR}$ = 0. The command will be latched internally off the data bus on the trailing edge of the $\overline{WR}$ pulse. Each 8 bit command contains an opcode from 2 to 5 bits in length, and one or more operands (see Table 2 below).

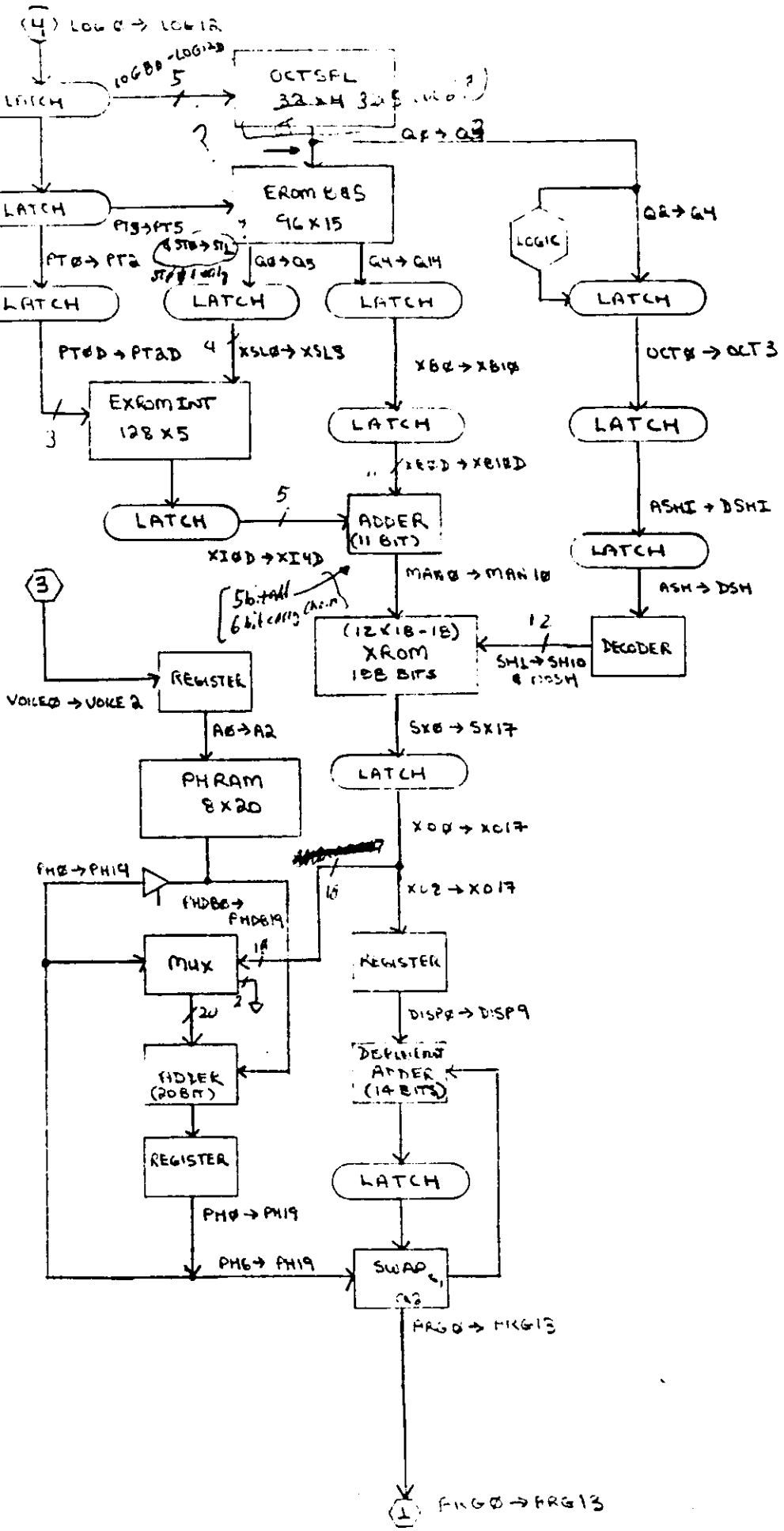
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	Command
0	0	0	0	1	V2	V1	V0	Write Fundamental Frequency Breakpoint
0	0	0	1	0	V2	V1	V0	Write Voice Type
0	0	0	1	1	V2	V1	V0	Read Current Fundamental Frequency
0	0	1	0	SO3	SO2	SO1	SO0	Write System Options Register
0	0	1	1	X	X	SC1	SC0	Write System Control Register
0	1	H5	H4	H3	H2	H1	H0	Write Harmonic Amplitude Breakpoint
1	0	HP4	HP3	HP2	HP1	HP0	D0	Write Last Harmonic Pair Flag (Load SC1 bit = 0)
1	0	N5	N4	N3	N2	N1	N0	Write Noise RAM (Load SC1 bit = 1)
1	1	H5	H4	H3	H2	H1	H0	Read Current Harmonic Amplitude

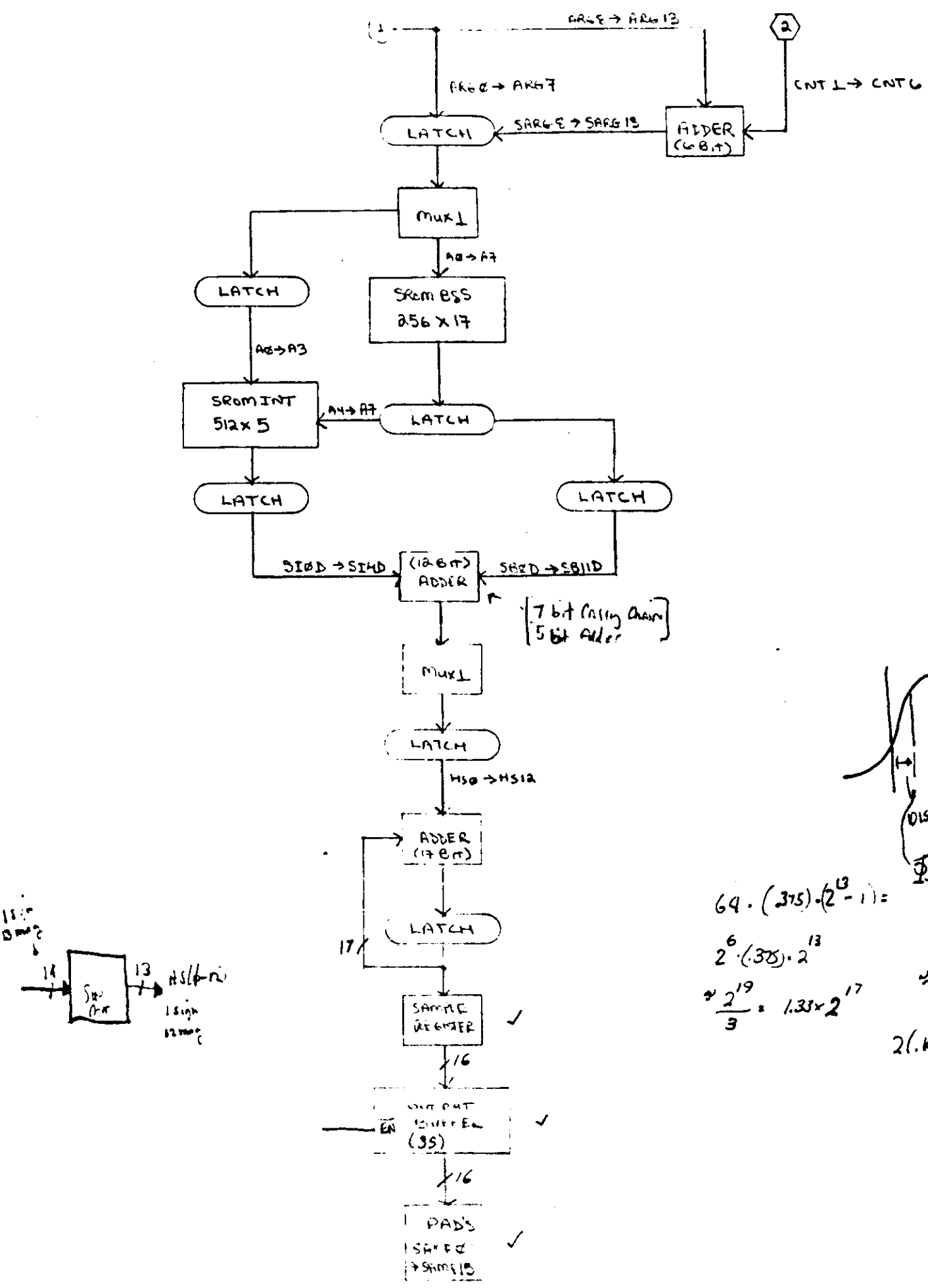
Table 2. AMY 1 Commands

V2-V0: Voice Number
SO3-SO0: System Options register bits
SC1-SC0: System Control register bits
H5-H0: Harmonic Number
HP4-HP0: Harmonic Pair Number
N5-N0: Noise RAM location
X: Don't care



When SEVRAN = ∅, force ZERB = 1


(4) LOG 0 → LOG 12
LATCH
LOGB0 - LOG12B
5
OCTSEL
32 x 4 3 x 5
QF → QB
EROM E&S
96 x 15
LATCH
PT9 → PT5
PT0 → PT2
ST0 → ST1
Q0 → Q5
Q4 → Q14
LOGIC
Q2 → Q4
LATCH
LATCH
LATCH
LATCH
PT0D → PT2D
4
XSL0 → XSL3
XB0 → XB19
OCT0 → OCT3
EXROM INST
128 x 5
3
LATCH
LATCH
XB1D → XB18D
LATCH
5
ADDER
(11 BIT)
ASHI → DSHI
XI0D → XI4D
LATCH
ASH → DSH
MAN0 → MAN10
5b. add
6 b. comp
3
(12 x 18 - 18)
XROM
108 BITS
12
SH1 → SH10
& ROSH
DECODER
REGISTER
VOICE0 → VOICE2
A0 → A2
SX0 → SX17
PHRAM
8 x 20
LATCH
XO0 → XO17
PH0 → PH19
PHDB0 → PHDB19
16
XL2 → XO17
MUX
16
2
20
REGISTER
DISP0 → DISP9
ADDER
(20 BIT)
DECREMENT ADDER
(14 BITS)
REGISTER
LATCH
PH0 → PH19
PH6 → PH19
SWAP
ARG0 → ARG13
1
FING0 → ARG13



$64 \cdot (.375) \cdot (2^{13} - 1) =$

$2^6 \cdot (.375) \cdot 2^{13}$

$\approx \frac{2^{19}}{3} \approx 1.33 \times 2^{17}$

$DLSB/2 = \frac{2^{10}}{2} = 2^9$

$\Phi_0 = \frac{2^9}{2^{14}} = \frac{1}{2^5}$

$= \frac{360}{3}$

$2(.14) = .36$