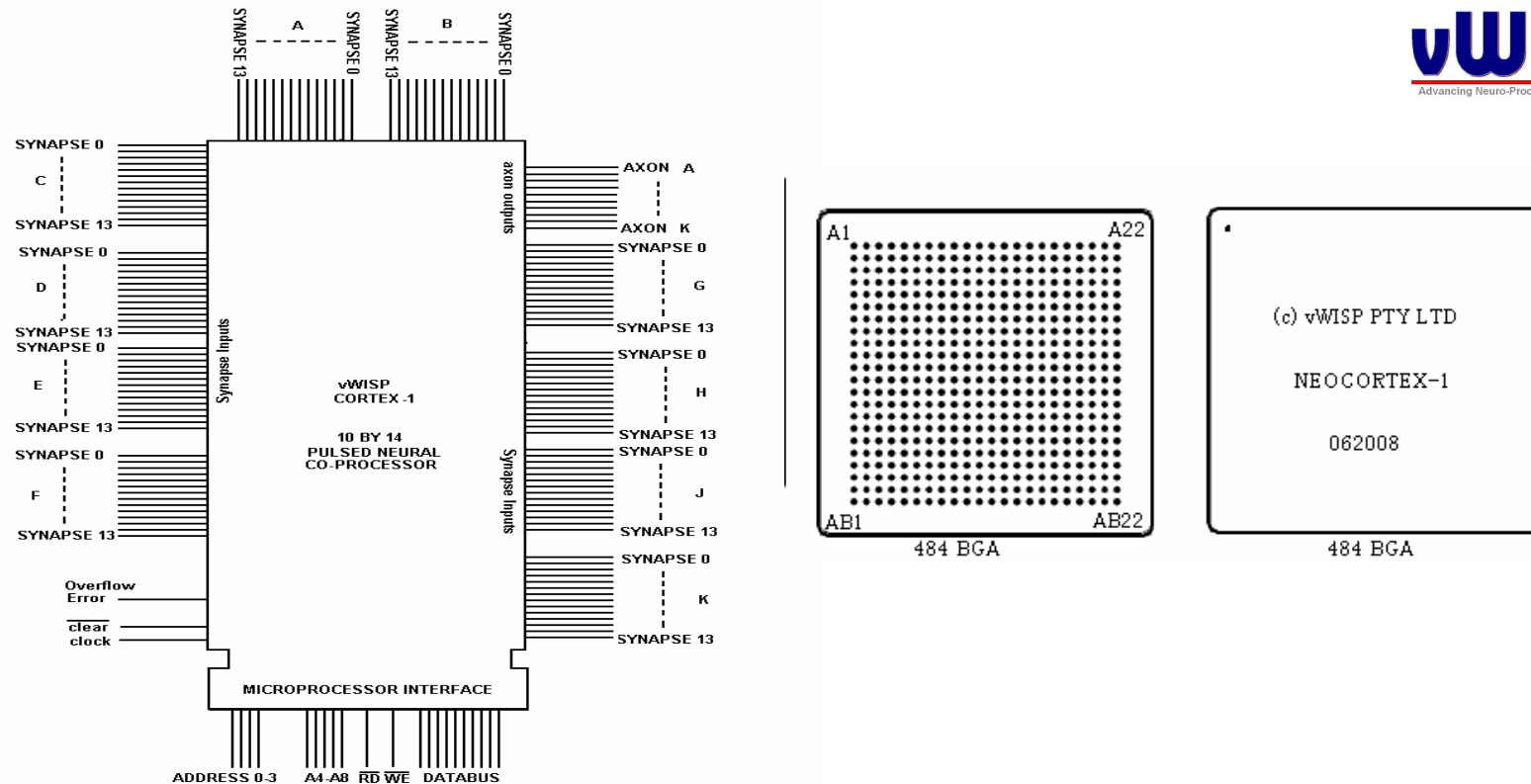
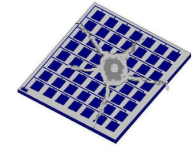


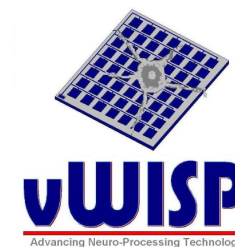
DATASHEET: **NeoCORTEX-1** PULSED NEURAL CO-PROCESSOR 140 Synapses x 10 Neurons © vWISP Pty. Ltd.

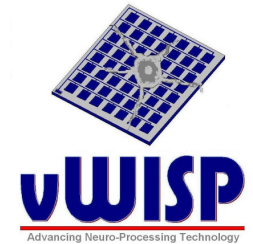


The vWISP NeoCortex-1 is a research version a new type of coprocessor. Like signal processors that appeared in the 1980's, the NeoCortex-1 is set to revolutionize the way neural networks are built. The device is stackable and contains 140 dynamic synapses and 10 neural processing junctions. The operation of the device is very similar to the way a biological neuron operates; when the input is pulsed the membrane potential is increased or decreased in a 'leaky integrator'. In the biological model the membrane potential increases as vesicles are passed into the synaptic cleft. Over time, the Ca⁺ value increments to a preset maximum value while the integrator value (PSP or membrane potential) declines, e.g. charge 'leaks' out of the integrator. The timing of input signals to each other, the time elapsed since the last input pulse, soma sensitivity and the axon delay are all factors of the transfer function. Later commercial devices will contain up to 15,000 neurons and 210,000 synapses and are organized in rows and columns.

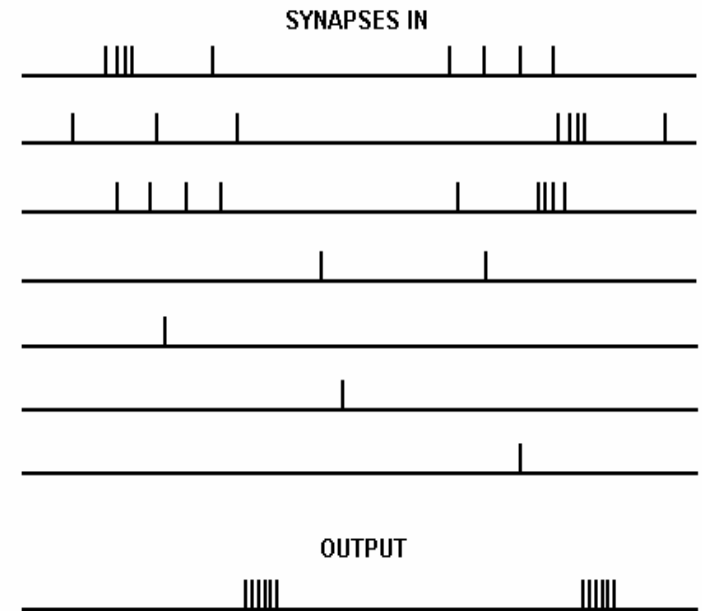
PROCESSOR REGISTERS

ADDRESS	REGISTER NAME	FUNCTION
00000000	CaPLUS0-0	Ca+ synapse 0 neuron 0
00000001	CaPLUS1-0	Ca+ synapse 1 neuron 0
00000010	CaPLUS2-0	Ca+ synapse 2 neuron 0
00000011	CaPLUS3-0	Ca+ synapse 3 neuron 0
00000100	CaPLUS4-0	Ca+ synapse 4 neuron 0
00000101	CaPLUS5-0	Ca+ synapse 5 neuron 0
00000110	CaPLUS6-0	Ca+ synapse 6 neuron 0
00000111	CaPLUS7-0	Ca+ synapse 7 neuron 0
00001000	CaPLUS8-0	Ca+ synapse 8 neuron 0
00001001	CaPLUS9-0	Ca+ synapse 9 neuron 0
00001010	CaPLUSA-0	Ca+ synapse 10 neuron 0
00001011	CaPLUSB-0	Ca+ synapse 11 neuron 0
00001100	CaPLUSC-0	Ca+ synapse 12 neuron 0
00001101	CaPLUSD-0	Ca+ synapse 13 neuron 0
00001110	SENS	Soma Sensitivity
00001111	DELAY	Axon Delay
0000xxxx	Neuron0	Select Neuron 0 registers (above)
00001xxxx	Neuron1	Select Neuron 1 registers
00010xxxx	Neuron2	Select Neuron 2 registers
00011xxxx	Neuron3	Select Neuron 3 registers
00100xxxx	Neuron4	Select Neuron 4 registers
00101xxxx	Neuron5	Select Neuron 5 registers
00110xxxx	Neuron6	Select Neuron 6 registers
00111xxxx	Neuron7	Select Neuron 7 Registers
01000xxxx	Neuron8	Select Neuron 8 Registers
01001xxxx	Neuron9	Select Neuron 9 Registers
	Registers are repeated for each neuron	





ADDRESS	REGISTER NAME	FUNCTION
01010xxxx	INHA0	Inhibit Mask bits for Neuron A low
01011xxxx	INHA8	Inhibit Mask bits for Neuron A high
01100xxxx	INHB0	Inhibit Mask bits for Neuron B low
01101xxxx	INHB8	Inhibit Mask bits for Neuron B high
01110	INHC0	Inhibit Mask bits for Neuron C low
01111	INHC8	Inhibit Mask bits for Neuron C high
10000	INHD0	Inhibit Mask bits for Neuron D low
10001	INHD8	Inhibit Mask bits for Neuron D high
10010	INHE0	Inhibit Mask bits for Neuron E low
10011	INHE8	Inhibit Mask bits for Neuron E high
10100	INHF0	Inhibit Mask bits for Neuron F low
10101	INHF8	Inhibit Mask bits for Neuron F high
10110	INHG0	Inhibit Mask bits for Neuron G low
10111	INHG8	Inhibit Mask bits for Neuron G high
11000	INHH0	Inhibit Mask bits for Neuron H low
11001	INHH8	Inhibit Mask bits for Neuron H high
11010	INHJ0	Inhibit Mask bits for Neuron J low
11011	INHJ8	Inhibit Mask bits for Neuron J high
11100	INHK0	Inhibit Mask bits for Neuron K low
11101	INHK8	Inhibit Mask bits for Neuron K high
11110	Not used	
11111	Not used	



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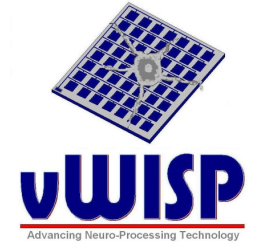
Description.

The vWISP Cortex-1 component contains 140 dynamic synapses and 10 neuron junctions. Each synapse can be inhibiting or excitatory, depending on the pattern written to the Inhibit mask registers. A '1' in the Inhibit mask sets the synapse to be excitatory. 14 bits are used in each Inhibit Mask, representing synapses 0-13. The top two bits are used for future enhancement.

The timing of the axon output depends on the soma sensitivity and the axon delay registers.

The axon delay is determined by:

$$\textit{Axon delay} = Tclk * DELAY$$



Tclk is the clock period and DELAY is the contents of the Axon Delay register. If the axon delay is set to a low value and the soma sensitivity is set to an appropriate value then the bursting behavior shown in the diagram of Page 2 will be observed.

Sequence of events

At an excitatory synapse, when an input pulse occurs, the then current Ca+ register value is added to the Membrane Potential of the Soma. The Soma Membrane Potential is the sum of all synapses PSP, including the negative values that are generated by Inhibitory synapses. The Ca+ value is cleared immediately after an input pulse and starts increasing to the value in the Ca+ register. The Membrane Potential is an internal register that can not be read. The Membrane potential decreases at half the Tclk rate. Whenever the Membrane Potential (PSP) reaches or exceeds the value contained in the Sensitivity register an output event is triggered. The output event repeats for as long as the summed PSP is higher or equal to the Sensitivity value. The PSP and Sensitivity values are 2's complement: 0 to 7Fh are positive values, 80h to FFh are negative whereby 80h is equivalent to -127. The CLK input is fast compared to the input pulses, typical by a factor 2^8 for an 8 bit system.

The decline in Membrane Potential is a function of the CLK signal. The Membrane Potential will decline to zero in

$$\textit{Tdecline} = 2 * \textit{Membrane potential} * Tclk$$

The current Ca+ value (available Ca+ in the synapse) is:

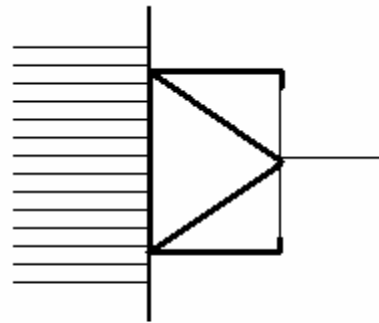
$$Ca+ = \sum_{Clk=1}^{max} \Delta t I$$

For example, assuming that only one synapse is pulsed, the clock period is $100 \mu\text{S}$ and the maximum Ca^+ value is set to $14h$ ($20d$).

The actual Ca^+ value will reach the maximum value after $0.0001 * 20 = 2 \text{ mS}$. During the same time the Membrane potential will have declined by $2\text{mS}/(2*100\mu\text{S}) = 10d$ or $0Ah$ unless the neuron was at equilibrium. If an input pulse is received at that time, the value $14h$ is added to $0Ah$ and the membrane potential is $01Eh$

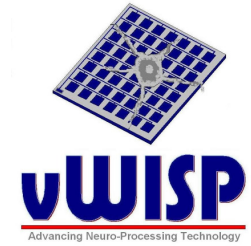
No trigger event occurs if the soma sensitivity is set to $43h$. After another 2 mS the Membrane potential has declined to $14h$ and $14h$ is added when a pulse occurs at this time. The membrane voltage is now $28h$. After 2 mS the membrane voltage is $1Eh$ and $14h$ is added, resulting in $32h$. Next, the membrane voltage declines to $28h$ plus $14h$ results in $3Ch$.

At the next input pulse a trigger event occurs; $3C$ declines to $32h$ plus $14h = 46h$. This declines to $43h$ in $3 * (2 * 100\mu\text{S})$. An output pulse will be generated, it's timing depending on the Axon delay value. The axon delay is $\text{DELAY} * \text{Tclk}$. Therefore if $\text{delay} > 3$ only a single pulse will be generated in this case. The sequence of five input pulses, 2 mS apart has resulted in the generation of a single output pulse. Output pulses are one clock period wide. The interval between pulses is $(\text{Delay} * \text{Tclk})$.



Dynamic Neuron Logic Symbol

PIN DESCRIPTIONS



Port	Function	Name	Signal Direction	Pin
1	Clear Synapses when 0 (not registers)	_CLEAR	IN	L5
2	Write Enable register	_WE	IN	AA10
3	CPU Address line 0	A0	IN	U9
4	CPU Address line 1	A1	IN	V9
5	CPU Address line 2	A2	IN	M2
6	CPU Address line 3	A3	IN	V15
7	CPU Address line 4	A4	IN	Y10
8	CPU Address line 5	A5	IN	W10
9	CPU Address line 6	A6	IN	AB6
10	CPU Address line 7	A7	IN	T11
11	CPU Address line 8	A8	IN	AA9
12	Axon output Neuron A	AXONA	OUT...	R2
13	Axon output Neuron B	AXONB	OUT...	AA4
14	Axon output Neuron C	AXONC	OUT...	M4
15	Axon output Neuron D	AXOND	OUT...	C11
16	Axon output Neuron E	AXONE	OUT...	AA17
17	Axon output Neuron F	AXONF	OUT...	Y11
18	Axon output Neuron G	AXONG	OUT...	W11
19	Axon output Neuron H	AXONH	OUT...	F12
20	Axon output Neuron J	AXONJ	OUT...	L16
21	Axon output Neuron K	AXONK	OUT...	D12
22	Clock signal	CLK	CLKB...	M19
23	Processor Data Bus	DATABUS[0]	IN	L17
24		DATABUS[1]	IN	L6
25		DATABUS[2]	IN	L4
26		DATABUS[3]	IN	L19
27		DATABUS[4]	IN	AA5
28		DATABUS[5]	IN	Y4
29		DATABUS[6]	IN	K7
30		DATABUS[7]	IN	B11
31	Synapse 0 Neuron A	SYNA[0]	IN	M5

32		SYNA[1]	IN	L2
33		SYNA[2]	IN	J4
34		SYNA[3]	IN	H7
35		SYNA[4]	IN	J5
36		SYNA[5]	IN	A4
37		SYNA[6]	IN	A5
38		SYNA[7]	IN	K4
39		SYNA[8]	IN	M8
40		SYNA[9]	IN	P7
41		SYNA[10]	IN	P3
42		SYNA[11]	IN	N4
43		SYNA[12]	IN	M7
44		SYNA[13]	IN	N6
45	Synapse 0 Neuron B	SYNB[0]	IN	N1
46		SYNB[1]	IN	H1
47		SYNB[2]	IN	K1
48		SYNB[3]	IN	E8
49		SYNB[4]	IN	B6
50		SYNB[5]	IN	N5
51		SYNB[6]	IN	AA6
52		SYNB[7]	IN	AA8
53		SYNB[8]	IN	W9
54		SYNB[9]	IN	AB5
55		SYNB[10]	IN	AB4
56		SYNB[11]	IN	R7
57		SYNB[12]	IN	U8
58		SYNB[13]	IN	U3
59	Synapse 0 Neuron C	SYNC[0]	IN	V8
60		SYNC[1]	IN	AB7
61		SYNC[2]	IN	A8
62		SYNC[3]	IN	M3
63		SYNC[4]	IN	AA7
64		SYNC[5]	IN	W8
65		SYNC[6]	IN	A7
66		SYNC[7]	IN	E9

67		SYNC[8]	IN	D9
68		SYNC[9]	IN	A6
69		SYNC[10]	IN	B7
70		SYNC[11]	IN	C7
71		SYNC[12]	IN	C6
72		SYNC[13]	IN	D8
73	Synapse 0 Neuron D	SYND[0]	IN	V10
74		SYND[1]	IN	G9
75		SYND[2]	IN	B8
76		SYND[3]	IN	B9
77		SYND[4]	IN	A9
78		SYND[5]	IN	C10
79		SYND[6]	IN	H11
80		SYND[7]	IN	G10
81		SYND[8]	IN	F11
82		SYND[9]	IN	D10
83		SYND[10]	IN	T10
84		SYND[11]	IN	G11
85		SYND[12]	IN	A11
86		SYND[13]	IN	A10
87	Synapse 0 Neuron E	SYNE[0]	IN	E12
88		SYNE[1]	IN	U13
89		SYNE[2]	IN	AB12
90		SYNE[3]	IN	AA19
91		SYNE[4]	IN	U14
92		SYNE[5]	IN	M21
93		SYNE[6]	IN	N17
94		SYNE[7]	IN	W16
95		SYNE[8]	IN	V16
96		SYNE[9]	IN	T22
97		SYNE[10]	IN	W17
98		SYNE[11]	IN	U22
99		SYNE[12]	IN	R19
100		SYNE[13]	IN	R22
101	Synapse 0 Neuron F	SYNF[0]	IN	AA18

102		SYNF[1]	IN	V13
103		SYNF[2]	IN	AB14
104		SYNF[3]	IN	W14
105		SYNF[4]	IN	AA16
106		SYNF[5]	IN	W15
107		SYNF[6]	IN	T13
108		SYNF[7]	IN	AB13
109		SYNF[8]	IN	AA11
110		SYNF[9]	IN	R11
111		SYNF[10]	IN	AA12
112		SYNF[11]	IN	Y12
113		SYNF[12]	IN	R12
114		SYNF[13]	IN	AB9
115	Synapse 0 Neuron G	SYNG[0]	IN	N16
116		SYNG[1]	IN	AB17
117		SYNG[2]	IN	AB16
118		SYNG[3]	IN	T14
119		SYNG[4]	IN	L15
120		SYNG[5]	IN	E13
121		SYNG[6]	IN	B13
122		SYNG[7]	IN	E14
123		SYNG[8]	IN	V14
124		SYNG[9]	IN	G13
125		SYNG[10]	IN	AA13
126		SYNG[11]	IN	G12
127		SYNG[12]	IN	B12
128		SYNG[13]	IN	U11
129	Synapse 0 Neuron H	SYNH[0]	IN	AB8
130		SYNH[1]	IN	U10
131		SYNH[2]	IN	T12
132		SYNH[3]	IN	U12
133		SYNH[4]	IN	V11
134		SYNH[5]	IN	V12
135		SYNH[6]	IN	D11
136		SYNH[7]	IN	A12

137		SYNH[8]	IN	D13
138		SYNH[9]	IN	F13
139		SYNH[10]	IN	AB15
140		SYNH[11]	IN	W13
141		SYNH[12]	IN	W12
142		SYNH[13]	IN	H12
143	Synapse 0 Neuron J	SYNJ[0]	IN	A13
144		SYNJ[1]	IN	G14
145		SYNJ[2]	IN	F14
146		SYNJ[3]	IN	K16
147		SYNJ[4]	IN	A15
148		SYNJ[5]	IN	A14
149		SYNJ[6]	IN	D14
150		SYNJ[7]	IN	A16
151		SYNJ[8]	IN	D15
152		SYNJ[9]	IN	M15
153		SYNJ[10]	IN	K17
154		SYNJ[11]	IN	K22
155		SYNJ[12]	IN	H22
156		SYNJ[13]	IN	L21
157	Synapse 0 Neuron K	SYNK[0]	IN	M16
158		SYNK[1]	IN	L22
159		SYNK[2]	IN	N22
160		SYNK[3]	IN	P22
161		SYNK[4]	IN	M17
162		SYNK[5]	IN	N21
163		SYNK[6]	IN	N18
164		SYNK[7]	IN	M20
165		SYNK[8]	IN	K19
166		SYNK[9]	IN	K20
167		SYNK[10]	IN	H19
168		SYNK[11]	IN	G18
169		SYNK[12]	IN	B16
170		SYNK[13]	IN	A17

TYPICAL APPLICATION

