Breadboard Design History

I designed a lot of LSIs in NEC Japan, Chips and Technologies USA, ASCII of America USA, Auctor Corporation USA, and SanDisk USA.

Most of the LSI design needed a breadboard to verify the LSI function real time working under actual system as well as for demonstration before the LSI becomes available. However, designing, making and debugging the breadboard are not easy. Dense expertise spreading over various technical fields (both hardware and software,,,) is indispensable. If you have not engaged in as well as not completed the breadboard related design work, you should not introduce yourself as an LSI logic designer. Have sane common sense.

LSI Product	Year	Random Logic	ROM Emulation		System Controller		
NEC µPD281/ <u>282</u> chipset	1972		Soldering/desoldering diodes directly on board		None (Unnecessary)		
NEC <u>µPD940</u>	1974	MOS SSIs	UVEPROM \rightarrow Diode short pin matrix board				
NEC <u>µPD1201</u>	1975		Wire memory (Nonvolatile)		<u>NEAC M4</u> mini computer		
NEC <u>µPD1205</u>	1976		Slow speed paper tape reader and puncher installed on <u>Teletype Model 33</u> to dump ROM code for computer simulation and for preparing photo mask data base				
NEC <u>µPD777</u>	1977	Bipolar TTLs	SRAM	NEC $\underline{TK-80}$ High speed paper tape reader and puncher to dump ROM code at the end of daily debug work			
NEC μPD7220/ <u>7220A</u>	1980			TRS-80 Z80 1.774MHz 8 bit personal computer (TRSDOS console) 5.25" Floppy Disk Drive to store ROM code at the end of daily debug work			
NEC <u>µPD72120</u>	1985			NEC PC-9801XA 8086 8MHz 16 bit personal computer (MSDOS console) 20MB Hard Disk Drive to store ROM code at the end of daily debug work			
Chips and Technologies 82C455/456/ <u>457</u>	1988	Computer	None (Unnecessary) Verify by so-called "Full screen simulation" limited to a portion of quarter screen ((160 out of 640) x (120 out of 480) from top-left most screen)				
ASCII of America DA7290/ <u>HD814102</u>	1993	Simulation	None (Unnecessary) Analyze and replay PCM audio sound data output by computer simulation, Encode the sound data and compare to the original MPEG compressed audio data				
Auctor Corporation Flash memory Controller	1995		SRAM		IBM PC Pentium 120MHz 64 bit personal computer (MS Windows 95/MSDOS console)		
SanDisk <u>USB to Flash memory Bridge</u>	2000	Altera FPGA			IBM PC Pentium III 550MHz 64 bit personal computer (MS Windows NT/MSDOS console)		

(1) NEC µPD281/282 chipset

I took charge of μ PD282 logic and mask layout design. Arithmetic Logic Unit, shift registers that stores BCD (Binary Coded Decimal) calculation data, timing controller, and so forth were integrated on μ PD282. Program ROM was integrated on μ PD281.

The ROM code was emulated by diodes soldered directly on ROM board (see example below). This was a primitive and inefficient approach not to be adopted. Every time the program flow is updated, the diodes are desoldered and/or soldered. It was so cumbersome and time consuming work. Actually, I had to work all over night for the desoldering and soldering work.

ROM size of μ PD281 was 384 x 13. The size was much bigger than an 32 x 16 example below.



32 x 16 Diode Matrix Board Example

Next day was a day of close friend's marriage. I failed to appear because I had to continue mask layout design work from that morning just after the overnight work. In the evening, I received a call that grand father passed away and attended the wake at Zushi Kanagawa prefecture.

Next morning, Mr. Matsumura, a department manager, came, politely bowed, and said "My condolences to your grand father". I was so surprised and grateful simultaneously because I was told "Oguchi-kun, although you may be a rookie......" (Refer to "LSI Products") from him a few month ago. Did he show remorse? Probably, not.

(2) NEC µPD940

At the beginning, I tried to apply UVEPROMs just emerged. However, I recognized that the UVEPROM programming needs handling a small hexadecimal keyboard on EPROM programmer for specifying both address and data one by one as well as handling an ultraviolet light for erasing data slowly. The reliability of UVEPROM itself was not sufficiently high as well.

Fortunately, I found a 16 x 16 diode short pin matrix boards at electronic parts market. Because the 16 x 16 matrix size was much smaller than the μ PD940 ROM size of 256 x 19, I had to order 20 pieces (The total number of short pin provided and diode assembled was 5,120 (20 x 16 x 16) each). Wow!



16 x 16 Diode Short Pin Matrix Board (Physical size is not so big, 3" x 3" x 1")

All the diodes have been already assembled in the matrix board. By inserting a short pin into a hole, a correspondent diode is connected.

I did wiring connection between the 20 pieces of the 16 x 16 matrix boards and made a 256 x 19 diode short pin matrix ROM board which operated as a key major electronic component of μ PD940 breadboard.

				-	
16x16 diode short pin matrix board	$A[2:1] = 0^{-3} \longrightarrow D19$ $A[2:1] = 0^{-3} \longrightarrow D18$ $A[2:1] = 0^{-3} \longrightarrow D17$	D17			
16x16 diode short pin matrix board	$A[2:1] = 0^{-3} \longrightarrow D16$ $A[2:1] = 0^{-3} \longrightarrow D15$ $A[2:1] = 0^{-3} \longrightarrow D14$ $A[2:1] = 0^{-3} \longrightarrow D13$	D16 D15 D14 D13			
16x16 diode short pin matrix board	$A[2:1] = 0^{-3} \longrightarrow D12$ $A[2:1] = 0^{-3} \longrightarrow D11$ $A[2:1] = 0^{-3} \longrightarrow D10$ $A[2:1] = 0^{-3} \longrightarrow D9$	D12 D11 D10 D9			
16x16 diode short pin matrix board	$A[2:1] = 0^{3} \longrightarrow D8$ $A[2:1] = 0^{3} \longrightarrow D7$ $A[2:1] = 0^{3} \longrightarrow D6$ $A[2:1] = 0^{3} \longrightarrow D6$	D8 D7 D6 D5			
16x16 diode short pin matrix board	$A[2:1] = 0 - 3$ \rightarrow $D4$ $A[2:1] = 0 - 3$ \rightarrow $D3$ $A[2:1] = 0 - 3$ \rightarrow $D2$ $A[2:1] = 0 - 3$ \rightarrow $D1$	D4 D3 D2 D1			
A[8:3] = 30~3fh	A[8:3] = 20~2fh	A[8:3] = 10~1fh	A[8:3] = 00~0fh	μΡD940	μ PD 946

256 x 19 Diode Short Pin Matrix Board (20 pieces of 16 x 16 Diode Short Pin Matrix Board) Assembled

This valuable ROM board I made was inherited to another μ PD946 development project which ROM size was 256 x 17 later on. It is clear that μ PD946 breadboard debug had to start after the μ PD940 breadboard debug had completely finished.

(3) NEC µPD1201 and µPD1205

The ROM size of µPD1201 became 1024 x 14, 4 times bigger than the one of µPD940. As a matter of course, the diode matrix board approach was abandoned.

Instead, an NEAC M4 mini computer along with a Teletype Model 33 detached from an old LSI tester was applied utilizing nonvolatile wire memory equipped inside. I updated ROM codes through keyboard of the teletype writer using NEAC M4 command.



Teletype Model 33

How to wake up NEAC M4;

(1) Type in short machine language codes of paper tape reader program through push buttons on front panel.

(2) Read a paper tape that contains a boot strap loader through paper tape reader equipped in the teletype writer.

On Saturday in late December 1971, Tanabe-san (田辺) and Sugaya-san (菅谷) rented an NEC mainframe at large computer room at NEC Tamagawa plant for 8 hours (9 AM to 5 PM). I brought IBM cards stored in a couple of boxes to do logic simulation. According to Tanabe-san, the main wire memory capacity is 96kB, amazingly smaller than PCs now available. Digital data had to be stored and accessed in/from magnetic tape drives mainly. Instead of paper tape in case of NEAC M4, Tanabe-san booted up the mainframe by using IBM cards putting in IBM card reader platform. The boot-up procedure was the same.

(3) NEC µPD72120

Augat wire wrap breadboard system was applied.

The size of the board is 370 mm x 280 mm x 30 mm (including wire wrap pin height).

Three 96 positions DIN 41612 male to male right angle connectors are assembled to connect inter-board signals and power and ground.

The weight of the board is 1,435 grams with three 96 positions DIN 41612 male connectors without parts installed under no parts wire wrapped (bare conditions).

Up to 442 pieces of 14 pin TTLs wire-wrapped with no space can be assembled. However, we initially specified 60% parts occupation per board to allow big logic change. The number of parts actually assembled was a lot fewer than the maximum.

μPD72120 breadboard system consists of 12 Augat boards.
 μPD72120 logic
 μPD72120 logic
 boards
 board

The 12 boards are allowed to slide through sturdy pipes like a curtain at hospital to ease debugging of a certain breadboard watching wire wrap side as well as parts side swaying the board.

The board holding attachment holds a breadboard by upper and lower board holding rail which depth is 5mm. The attachment has three blocks of 96 positions DIN 41612 female to male connector that accept plugging in three blocks of 96 positions DIN 41612 male to male right angle connector on board.

When insert a breadboard into the attachment, slide a board between board holding rails and plug three DIN 41612 connectors on board into three DIN 41612 connectors' receptors on system. At this moment, board removal clip levers becomes flat. When removing a board, lift the board removal clip levers. Using the leverage, a board can be unplugged from system.

µPD72120 design engineering team made breadboard schematics using bipolar TTLs and SRAMs for emulating preprocessor and drawing processor ROM to be programmed by a programmer I wrote in Basic language running on NEC PC9801XA 16 bit personal computer.

As an ordinary way, we outsourced to breadboard manufacturing contractors handing the breadboard schematics. They chose and ordered the Augat breadboard system along with electronic parts as well as distributed the entire μ PD72120 logic into 11 boards referring to the μ PD72120 functional block diagram and made inter-board connection schematics themselves. Then, they did the entire wire-wrapping, check the connection of the breadboard system, and we received μ PD72120 breadboard system.

Soon after I reinforced power and ground, I was able to start debugging the breadboard utilizing a logic analyzer along with an evaluation software I already made running on NEC PC9801XA 16 bit personal computer. Excellent job!!

I solely handled the following hardware instruments for the µPD72120 breadboard work excluding Augat system. (1) Logic analyzer

- (2) NEC PC9801XA 16 bit personal computer with color monitor TV, external HDD, keyboard, and mouse
- (3) NEC N5200 (APC) 16 bit personal computer with keyboard and mouse
- (4) Large high resolution color monitor TV (H=32kHz) continuously using from µPD7220 breadboard debug work

(5) 132 columns Kanji color dot matrix impact printer

In 1985, FPGA was not suitable for LSI functional verification because of the reasons below.

- Slow speed
- Small gate counts
- Not matured yet software-wise as well as hardware-wise
- NEC did not manufacture FPGAs due to excessive worry of the technical support, manufactured only gate array.

µPD72120 was a sole LSI that succeeded the breadboard debug running under actual working system in 1986. All the breadboards applied to other new LSI product developments in NEC did not function. Such breadboard systems were miserably scrapped. This clearly indicated the decline of NEC semiconductor business occurred soon after.



Front View (Component Side)



Three blocks of 96 positions DIN 41612 M to M right angle connectors for inter-board signals and power supply



Wire wrap side view



Side view (\approx 7,000 (over 442 x 14) wire wrap pins are already installed)







<Side view> Breadboard #12 is under debug





Female to male 63 positions DIN 41612 connector (On system)



Male to male right angle 63 positions DIN 41612 connector (On Board)



Female to male 63 positions DIN 41612 connector (On System)



Three M to M right angle DIN41612s on board are plugged into three F to M DIN41612s



Board removal clip levers (black) is close (Plugged into DIN 41612 female connector on system)



Board removal clip levers (black) is open (Detached from DIN 41612 female connector on system)



Manual unwrap tool, Manual unwrap/wire strip/wrap tool, Semi-automatic manual wrapper (Left, Top-to-bottom) Wire stripper, Wire wrapping wire 30 AWG (Right, Top-to-bottom)