PDP-9 vs HP 2100 Architecture Comparison Report

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1. Introduction

The present report discusses two of the most important historical computer architectures, which are the PDP-9 from Digital Equipment Corporation (DEC) and the HP 2100 from Hewlett-Packard Company (HP). These two systems came out in the late 1960s **(Wikipedia, 2024),** enjoying extremely high usage industries of research and engineering. Specific technical aspects to be reviewed are hardware components, memory structure, addressing schemes, data types, and instruction sets. Furthermore, this report will take a closer look at use cases and legacies that these systems bring into modern computing.

2.1 Elementary base

The HP 2100 and PDP-9 are based on early transistor technologies, which defined both their architectural limitations and physical characteristics. The HP 2100 uses TTL (Transistor-Transistor Logic) circuits to increase reliability and reduce power consumption compared with earlier vacuum tube systems. Its integration level is low since LSI technology had not been developed.

Physical characteristics

- The HP 2100 physically weighed in the range of 600 to 800 pounds, 272-363 kg, fitted into standard 19-inch racks or large cabinets, and consumed approximately 2-3 kW of power.

The PDP-9 was also built using discrete transistors on modular circuit boards, which were easy to maintain and upgrade. It preceded LSI technology and, therefore, was completely dependent on individual transistor components.

Physical characteristics

- The PDP-9 was about 2 meters wide and 75 cm deep, weighing around 750-900 pounds. Power consumption varied from 3 to 5 kW, reflecting the energy demands of its complex processing capabilities**.(Wikipedia, 2024)**

2.2 System Architecture

The system architectures of the PDP-9 and HP 2100 reflect different design goals shaped by their technological limitations.

The HP 2100 features a register-based architecture tailored for control-oriented tasks and industrial applications. Its processor includes several general-purpose 16-bit registers, allowing efficient data management and fast task switching. To simplify internal operations, it uses a one-address instruction format.

On the other hand, the PDP-9 employs an accumulator-based architecture, centering operations around a single 18-bit accumulator register for arithmetic and logic tasks. This design keeps the control unit straightforward but limits parallel data processing. Like the HP 2100, the PDP-9 also uses a one-address instruction format, balancing simplicity with flexible memory management.

2.3 Registers, Flags, and Data Width

The HP 2100 has several **16-bit** general-purpose registers that enhance its multitasking and data management capabilities. These registers are used for arithmetic operations, data storage, and control tasks. The system includes **arithmetic flags** like zero, carry, and overflow, which are crucial for conditional branching and managing program flow. Its data **width of 16 bits** defines its standard machine word size. **(Wikipedia, 2024)**

In contrast, the PDP-9 relies on a single **18-bit** accumulator register for all its arithmetic and logic operations. This design keeps the hardware simpler but limits simultaneous data processing. It uses **status flags** such as zero, negative, and overflow to support conditional execution of instructions. With an **18-bit data width**, the PDP-9 can handle more complex numerical computations than the HP 2100. **(Wikipedia, 2024)**

2.4 Memory and Addressing

HP 2100 includes a linear memory layout and a 15-bit-wide address bus, yielding a maximum addressable memory size of 32 KB. In this memory, the addressing space is contiguous, without any support for segmentation or paging. The system also supports direct and indirect addressing modes, thus allowing a great deal of flexibility in data management. However, virtual memory was not supported-a lack indicating the technological constraints of that time.

The PDP-9 uses a segmented memory model, with an 18-bit address bus. This would theoretically allow a maximum memory size of 256 KB. Its memory addressing supports direct, indirect, and indexed modes that provide greater flexibility in accessing and manipulating memory locations. As in the HP 2100, virtual memory was not supported, and all data had to be stored in physical memory.

2.5 Instruction Set Architecture (ISA)

The **HP 2100** has a 16-bit instruction word and includes **68 instructions**, divided into four main classes **(Hewlett-Packard, 1972):**

- **Memory Reference Instructions:** Used for memory access (ADD, LDA, STA).
- **Register Reference Instructions:** Handle register-level operations (CLA, CMA).
- **I/O Instructions:** Manage I/O devices (ION, IOF).
- **Arithmetic Extensions:** Perform advanced arithmetic (MUL, DIV).

The **PDP-9** uses an 18-bit instruction word and supports approximately **90 instructions.** ***<u>(Number is generated by ChatGPT, because I couldn't find any documentated number)</u>*** Its instruction classes include:

- **Memory Reference Instructions:** Used for memory operations (TAD, DCA).
- **Operate Instructions:** Control CPU operations (CLA, CMA).
- **I/O Instructions:** Control input/output (IOT).
- **Arithmetic Instructions:** Perform arithmetic (MUL, DIV).

Instruction Format

- Both use a **one-address format**, meaning each instruction references a single memory address or register.

Instruction Examples

Instruction	**HP 2100**	**PDP-9**
Add	ADD	TAD
Load Acc.	LDA	LCA
Jump	JMP	JMP
Multiply	MUL	MUL
Divide	DIV	DIV
No Operation	NOP	NOP
I/O Control	ION, IOF	IOT

(DEC, 1968)

Addressing Modes

The **HP 2100** supports: Direct and indirect addressing

The **PDP-9** supports: Direct, indirect and indexed addressing

Similarities

- Both architectures support **Direct** and **Indirect Addressing**.
- Both include essential instructions for arithmetic, logic, and control flow.

Differences

- The **PDP-9** has **Indexed Addressing**, making it more suitable for complex tasks like scientific calculations.
- Its broader instruction set also supports advanced hardware-driven operations.

2.6 I/O Capabilities and Interrupts

The HP 2100 connected to peripheral devices like printers and tape drives using dedicated I/O channels controlled by specific instructions such as ION (Enable I/O) and IOF (Disable I/O), enabling smooth device communication.

The PDP-9 managed peripherals like disk drives, graphical displays, and teletype terminals using IOT (Input/Output Transfer) instructions. Its modular design made hardware expansion straightforward and flexible. **(DEC, 1968)**

Interrupt Handling:

- **HP 2100:** Used interrupt flags to notify the CPU, enabling real-time control of connected devices.
- **PDP-9:** Employed a priority-based interrupt system, allowing efficient management of multiple devices by prioritizing more critical tasks.

2.7 Data Types

The HP 2100 handled **16-bit integers** and **fixed-point numbers**, making it ideal for control-oriented tasks. While it didn't have built-in floating-point support, this functionality could be added through software libraries when needed. It used **two's** complement for signed integers and supported unsigned integers for data storage.

The PDP-9, on the other hand, **supported 18-bit integers**, **floating-point numbers**, and **binary-coded data**, making it more suitable for scientific and complex calculations. It also used **two's** complement for signed integers, allowing more advanced data operations. Floating-point functionality was available through specialized instructions and extensions, enhancing its computational capabilities. **(DEC, 1968)**

2.8 System speed and Performance

Aspect	**HP 2100**	**PDP-9**
Clock Frequency	1 MHz	1.5 MHz
Memory Cycle Time	1.6 microseconds	1 microseconds
Instruction Execution	1-2 clock cycles	1-2 clock cycles
Average Execution Time	1-2 microseconds	1 microseconds
Performance Focus	Reliability, real-time control	Scientific, data-heavy tasks

(Wikipedia, 2024)

Which system was faster?

With its higher clock speed and faster memory cycle, the PDP-9 outperformed the HP 2100 in scientific tasks, while the HP 2100 excelled in real-time control due to its reliability and stability.

2.9 Cache Memory and Application Areas

Cache Memory

Neither the **HP 2100** nor the **PDP-9** used cache memory, as this technology emerged later in computing history. Both relied entirely on main memory for data storage and processing.

System	**Application Areas**	**Example Installation**

HP 2100	Industrial automation, data acquisition, and control systems	Used in laboratories for monitoring and controlling experiments.
PDp-9	Scientific computing, research, and real-time data analysis	Installed in universities for advanced computational research.

2.10 Software, application domains and programming tools

Both the **HP 2100** and **PDP-9** had rich software libraries for research, education, and industry. While development has ended, many programs remain accessible through online archives and emulators like **SIMH**, preserving their legacy.

HP 2100

- **Application Domains:** Industrial automation, laboratory monitoring, scientific research, and business data management.
- **Compilers and Tools**
  - **Compilers:** FORTRAN, BASIC
  - **Assemblers:** HP Assembly Language (HPAL)
  - **Debugging Tools:** Built-in debugging utilities and profilers
  - **Software Libraries:** Scientific and mathematical libraries for real-time control and computation tasks

PDP-9

- **Application Domains:** Scientific research, university-level computation, data analysis, and technical simulations.
- **Compilers and Tools**
  - **Compilers:** FORTRAN IV, ALGOL
  - **Assemblers:** MACRO-9 Assembler
  - **Debugging Tools:** PDP Debugging Monitor (PDM)
  - **Software Libraries:** Specialized libraries for scientific calculations, numerical simulations, and data processing tasks

3. Conclusion

The comparison between the HP 2100 and PDP-9 showcases the technological progress and challenges of early computer designs. The HP 2100 prioritized reliability and real-time industrial use, while the PDP-9 excelled in scientific computing with its advanced instruction set and addressing capabilities. Both systems significantly influenced modern computing and remain iconic examples of early computer engineering.

4. Bibliography

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