PROCESSORS OF THE GAME BOY SERIES

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Overview

- Game Boy
  - Zilog Z80
- Game Boy Advanced
  - ARM7TDMI
- Nintendo Dual Screen
  - ARM946E-S & ARM7TDMI
- Nintendo Dual Screen 3D
  - ARM11 & PICA200
GAME BOY

Nintendo started prototyping in 1987 a device that was not to use the latest cutting edge technology, but instead to use a processor that was less expensive and designed for mobility.

Thus Gunpei Yokoi, Nintendo designer, chose the zilog z80 to be implemented in their prototype. A processor that was on the market since in 1976.

Prototyping took 2 years until the Game Boy hit the market in 1989.
Zilog was started by Ralph Ungergerman and Federico Faggin Los Altos, CA in 1974.

Ungergerman and Faggin both worked for Intel and left due to recent changes at Intel.

In 1975 Exxon Enterprises decided to finance Zilog for the Z80 project.

By July of 1976 Zilog put the Z80 on the market. It took about about 1 year and 2 months.

The Z80 was the chip that started Zilog.
Since the Z80 has been manufactured it has been used in a variety of consumer electronics systems.

The systems ranged from fax machines, photocopiers, TI graphing calculators, credit card machines and desktop computers like the Commodore 128.

In many music systems, the Z80 has been used as a realtime audio codec and a MIDI controller.

In game systems, the Z80 has been used in coin-operated arcade games, several SEGA systems, and of course the Gameboy.
For the minimum requirements to run a Z80 CPU are:
- A Single 5V Power Supply
- External Memory (RAM, ROM, PROM)
- A Simple Oscillator
- An I/O Circuit
ZILOG Z80 – MEMORY

The Z80 had:
- Stack Pointer
- Two Index Registers
- Program Counter
- Interrupt Register
- Refresh Register

The Game Boy had:
- 8KB Internal RAM
- 32KB Cartridge ROM
The Z80 is a 8-bit CISC architecture.

Very similar to the Intel 8080.

158 Different Instructions (Including all 78 from 8080)
Nintendo Modified the ISA for the Game Boy

Instructions fall into one of eight categories:
- Load and Exchange
- Arithmetic and Logical
- Bit Manipulation
- Jump, Call, & Return
- Input/Output
- Block Transfer and Search
- Rotate and Shift
- Bit Manipulation
- Basic CPU Control
ZILOG Z80 – INTERRUPTS

The Z80 had one interrupt line.

The interrupt devices are daisy chained with the highest priority given to the device closest to the power line.

![Diagram of interrupt devices](image-url)
ZILOG Z80 – MODERN

Moog Memorymoog, Minimoog, Memorymoog Plus

TI-82/83/85/86

Intoxilyzer 5000EN

Emulation
GAMEBOY ADVANCE

The Gameboy Advance was released on in 2001.

The processor used (the ARM7tdmi) was on market for 7 years before the GBA was manufactured.
ARM7TDMI - HISTORY & ARCHITECTURE

Part of the ARM7 family, manufactured in 1994.

Supported both 32-bit and 16-bit instructions depending on the mode. (This change in mode was how backwards compatibility was possible between Gameboy and GBA games).

32bit RISC CPU, 16.78MHz, 32bit opcodes (GBA)
Z80/8080-style 8bit CPU, 4.19MHz (gameboy)

"The ARM7TDMI core has a Von Neumann architecture, with a single 32-bit data bus carrying both instructions and data. Only load, store, and swap instructions can access data from memory." -ARM
The ARM7TDMI had:

- 31 general 32-bit registers
- 6 status registers
- 16 KB BIOS ROM
- 32 KB internal RAM (IWRAM) unified

The GameBoy had:

- 256 KB external (to the processor) work RAM
- Up to 8 MB of GamePak ROM
ARM7TDMI – ISA

ARMv4T architecture
2 different modes

ARM instruction

Move- 8
Logical- 6
Load- 14
Swap- 2
Software interrupt- 1

Arithmetic- 14
Branch- 3
Store- 11
Coprocessors- 5

Thumb instruction

Move- 4
Logical- 6
Branch- 18
Store- 8
Software interrupt- 1

Arithmetic- 19
Shift/Rotate- 4
Load- 13
Push/Pop- 4
ARM7TDMI – INTERRUPTS

The ARM7TDMI had an interrupt register called 4000130h.

The GBA used this register as KEYINPUT - Key Status (Register)
ARM7TDMI – MODERN

Claimed to be the most widely used 32-bit risc

Used in:
- iPods
- Routers
- (portable media player)
- and the Roomba 500..

- Nokia phones
- Sirius Satellite Radio
- JuiceBox
- SEGA Dreamcast

...
- Released Nov. 21, 2004
  - Processor Released in 2000
- Dual Screen Technology
- Voice Recognition Capabilities
- 802.11 Wireless
- Processors Used
  1x ARM946E-S, 66 MHz
  1x ARM7TDMI, 33 MHz
ARM946E-S - ARCHITECTURE

32-bit RISC

Moved from Von-Neumann Architecture to Harvard Architecture

Uses 5 Stage Pipeline

Floating Point Hardware Support
ARM946E-S – MEMORY

Cache from 4KB 1MB

Split Cache with Independent Size

Four-Way Set-Associative
ARM946E-S – BLOCK DIAGRAM
ARM946E-S – COPROCESSOR DIAGRAM

ARM946E-S processor

CHSEX[1:0]

CHSDE[1:0]

CPDIN[31:0]

Coproprocessor interface block

Handshaking logic

Data interface logic

Coproprocessor

VFP9 coprocessor

Coprocessor 1

Coprocessor 2

Coprocessor instructions, data and control signals from ARM946E-S core
ARM946E-S – ISA

ARMv5TE 32-bit with DSP Extension
- Move - 4
- Logical - 6
- Swap -2
- Breakpoint - 1
- Software Interrupts - 1
- Arithmetic - 13
- Branch - 4
- Store - 4
- Coprocessor - 5
ARM946E-S – INTERRUPTS

Capable of IRQ and FIQ

4000210h - NDS9/NDS7 - IE - 32bit - Interrupt Enable (R/W)
4000214h - NDS9/NDS7 - IF - 32bit - Interrupt Request Flags (R/W)

Bit 0-6  Same as GBA
Bit 7    NDS7 only: SIO/RCNT/RTC (Real Time Clock)
Bit 8..  Same as GBA
Bit 16   IPC Sync
Bit 17   IPC Send FIFO Empty
Bit 18   IPC Recv FIFO Not Empty
Bit 19   Game Card Data Transfer Completion
Bit 20   Game Card IREQ_MC
Bit 21   NDS9 only: Geometry Command FIFO
Bit 22   NDS7 only: Screens unfolding
Bit 23   NDS7 only: SPI bus
Bit 24   NDS7 only: Wifi
Bit 25-31 Not used
ARM946E-S – MODERN

Lexmark Genesis

TI DM6446

TI DM355

Wavecom Q26 Extreme
NINTENDO 3DS

Released Feb. 26, 2011

Processor used-
- Dual ARM11, 266 MHz - Main Processors
- PICA200, 133 MHz - GPU

2.4 GHz WPA/WPA2
- IEEE802.11 b/g
## CONCLUSION

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<th>Game Boy</th>
<th>Game Boy Advanced</th>
<th>Nintendo DS</th>
<th>Nintendo 3DS</th>
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<tbody>
<tr>
<td><strong>Release Year</strong></td>
<td>1989</td>
<td>2001</td>
<td>2004</td>
<td>2011</td>
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<tr>
<td><strong>Processor</strong></td>
<td>Zilog Z80</td>
<td>ARM7</td>
<td>ARM9</td>
<td>ARM11</td>
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<tr>
<td><strong>Speed</strong></td>
<td>4.19 MHz</td>
<td>16.78 MHz</td>
<td>66 MHz - 133MHz</td>
<td>266 MHz</td>
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<tr>
<td><strong>Release Year</strong></td>
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<td><strong>Memory</strong></td>
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<td>128MB</td>
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<td><strong>Availability</strong></td>
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<td>Available</td>
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<tr>
<td><strong>Internal Flash</strong></td>
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<td>None</td>
<td>256kB - 256MB NAND</td>
<td>2GB - NAND</td>
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