Embedded Microprocessors
Overview

• Items to be covered:
  • **Embedded Microprocessors**
    • Special purpose circuit board MPU
    • May have integrated I/O Board or separate I/O Board
    • Slot Machine Backplane
  • **CPU’s Interaction with the other system components**
    • μP  Focused View of a Typical Block Diagram of a Slot Machine
      (Page 2.1.1.6)
    • Microprocessor Based Slot Machine Organization and Data flow
    • Embedded Slot Machine RISC with μP parallel command execution
      • Instruction Formats
      • Instructions
  • **S-Plus Block Diagram**
  • **Players Edge+ Block Diagram**
Embedded Microprocessors

• The first computerized Slot Machines utilized an Embedded Microprocessor built on a special purpose electronic circuit board – often referred as the CPU or MPU

  • Mounted in a card cage
  • The CPU or MPU plugged in to the Slot Machine Backplane
  • May have had integrated I/O circuitry or a separate I/O board, and sound cards
  • Embedded Microprocessor Integrated Circuit
  • Programs stored on EEPROMS or Flash Memory Modules
Embedded Microprocessors

• Embedded Microprocessor based CPU’s are found in older Slot Machines:
  • Aristocrat MAV500/540’s
  • Bally S6000
  • IGT S2000 & GameKings
  • Konami KP2 & KP3 processor games
  • WMS CPU-NXT2

• Newer Slot Machines used today have Motherboard based Microprocessor’s – same as a desktop PC
µP  Focused View of a Typical Block Diagram of a Slot Machine
Microprocessor Based Slot Machine Organization and Data flow

• Major Components
  • Every µP based slot machine contains at least:
    • Arithmetic Logic Unit (ALU)
    • Memory Unit
    • Control Unit
    • Input Unit
    • Output Unit
  • Interconnection of these is shown on the previous slide
    • Arrows indicate direction of data, info, and control signal flow
    • Large arrows indicate data or information flow
      • Using a large number of parallel lines (8, 16, 32, or 64) – A Bus
    • Smaller arrows indicate the flow of control signals
      • Usually they use one or a small number of lines
Microprocessor Based Slot Machine Organization and Data flow

• **ALU**
  • Area of the machine that performs
    • Arithmetic operations: addition, subtraction, etc.
    • Logical operations: AND, OR, XOR, incrementing, etc.
  • The operation to be performed is determined by signals from the control unit (arrow 1)
  • The data that are to be operated on by the ALU can come from either the Memory Unit (arrow 2) or the Input Unit (arrow 3)
  • Results of the ALU’s operation can go to:
    • Output Unit (arrow 5)
    • Memory Unit (arrow 4)

• **Memory Unit**
  • The memory stores information in groups called bytes
Microprocessor Based Slot Machine Organization and Data flow

• Memory Unit
  • The stored bytes can contain instructions (program) of the μP or data
  • The operation of the Memory is controlled by signals
    • From the control Unit (arrow 6)
• Information in Memory
  • Accessed (aka Read) by addresses provided from the control unit (arrow 7)
  • The information can be sent
    • To the Control Unit (arrow 11)
    • To ALU (Arrow 2)
    • To the Output Unit (arrow 9)
    • Destination of the data is determined by control signals (arrow 6)
• Written (aka stored) to Memory
  • From the ALU (arrow 4)
Microprocessor Based Slot Machine Organization and Data flow

• Memory Unit
  • Information in Memory
    • Written (aka stored) to Memory
      • From the Input Unit (arrow 8)
      • Source of the data is determined by control signals (arrow 6)

• Input Unit
  • Consists of all the devices that collect/take eternal information for input to the slot machine
    • Collected information can be put into
      • The ALU (arrow 3)
      • Memory (arrow 8)
    • Destination determined by the control signal (arrow 10)
  • Some common Input Devices
    • Player Panel Switches, Push Button switches, reel optics
Microprocessor Based Slot Machine Organization and Data flow

• **Input Unit**
  • **Some common Input Devices**
    • Touch screens, door open optics, validators, hopper empty sensor, etc.

• **Output Unit**
  • **Consists of all the devices that are used to transfer information from the slot machine to the “outside”**
    • information can come from
      • The ALU (arrow 5)
      • Memory (arrow 9)
    • Destination determined by the control signal (arrow 12)
  • **Some common Output Devices**
    • LED readouts, stepper reels, sound systems, video displays
Microprocessor Based Slot Machine Organization and Data flow

• Output Unit
  • Some common Output Devices
    • Hopper output to the coin tray, lights, etc

• Interfacing is a key aspect of Input & Output Units
  • Most devices aren’t compatible with µPs
    • Different voltage and current levels
      • The hopper operates need a relay/switch to apply/remove higher DC voltages
    • Different data/address line structures
      • µP use data/address buses
      • Switches use one line
      • 7-segment LED displays need BCD-to-7-segment converters
      • Video terminals receive and send information as serial data
Microprocessor Based Slot Machine Organization and Data flow

• Control Unit
  • Directs the operation of all the other units by providing
    • Timing signals
    • Control signals: R/W, clock signals used by devices like RAM, ROM, and I/O devices
  • Contains all the logic and timing circuits necessary to execute all of the system’s commands

• Common tasks
  • Fetching an instruction from memory
    • Address of the instruction is sent to memory (arrow 7)
    • A Read control signal is sent to memory (arrow 6)
    • The instruction stored at that location is transferred to the Control Unit (arrow 11)
  • Instruction Execution
    • The instruction is decoded from its stored binary form
Microprocessor Based Slot Machine Organization and Data flow

• Control Unit
  • Common tasks
    • Instruction Execution
      • The decoded instruction guides the control unit to send the necessary signals to the other units to execute the instruction
    • The fetch and execute tasks are continually performed
      • Until the system is reset or turned off

• Central Processing Unit (CPU)
  • At a minimum contains the ALU and Control Unit
    • Some also contain a some interface devices
      • Called µControllers
  • Also contain short term storage in the form of registers
    • Each register can contain a whole µP word
Microprocessor Based Slot Machine Organization and Data flow

• Central Processing Unit (CPU)
  • Also can contain cache memory
    • Used to hold the most likely next few instructions
      • Instructions stored are determined by guessing algorithms
    • Used to hold the most likely needed data – again determined by guessing algorithms

• Registers are a key part of μPs
  • Internal devices that aid both the Control Unit and the ALU
    • Each stores a μP word of data, instructions or addresses
    • Each μP word is one or more bytes long: 1, 2, 4, or 8 bytes long
  • Some key functions
    • Holding data that the ALU is processing
Microprocessor Based Slot Machine Organization and Data flow

• Registers are a key part of µPs
  • Some key functions
    • Program Counter
      • Keeps track of the addresses that are having their data fetched from memory
      • Critical task – sometimes the next instruction is in the next address after the current address. In that case the register is incremented and the next instruction fetched
    • Storing instructions that are being decoded
    • Data Pointer – holds the address of the data being fetched from memory
    • Many general purpose storage and counting registers which are used by programs as needed
Embedded Slot Machine RISC with μP Parallel Command Execution

- Reduced Instruction Set Computer – RISC
  - Uses a small number of simple instructions that are processed very quickly
    - The Intel 80X86 architecture that is the basis of most PCs have a much larger set of instructions
      - If given the same clock rate take longer to complete
    - A type that is in many slot machines from various manufactures
      - 80960 – Intel’s product name is I960
      - It has a much more complicated internal structure than the generic ones shown before

![Diagram of 80960SA Processor’s Highly Parallel Architecture](image)
Embedded Slot Machine RISC with μP Parallel Command Execution

• Reduced Instruction Set Computer – RISC
  • Key aspects
    • Large Register Set of thirty-two 32-bit registers.
      • Having a large number of registers reduces the number of times that a processor needs to access memory.
      • Optimizes execution speed.
    • Load/Store Architecture.
      • As such, only the LOAD and STORE instructions reference memory; all other instructions operate on registers.
      • Simplifies instruction decoding and is used in combination with other techniques to increase parallelism
    • Simple Instruction Formats.
      • To simplify the instruction decoder, there are only five instruction formats; each instruction uses only one format.
**Embedded Slot Machine RISC with µP Parallel Command Execution**

- **Reduced Instruction Set Computer – RISC**
  - **Key aspects**
    - Simple Instruction Formats.
Embedded Slot Machine RISC with μP Parallel Command Execution

• Reduced Instruction Set Computer – RISC
  • Key aspects
    • Overlapped Instruction Execution
      • Load operations allow execution of subsequent instructions to continue before the data has been returned from memory, so that these instructions can overlap the load of data from memory
      • Subsequent unrelated instructions may be executed while the conditional instruction is pending.
    • Cache Bypass
      • If a cache miss occurs, the processor fetches the needed instruction then sends it on to the instruction decoder at the same time it updates the cache. Thus, no extra time is spent to load and read the cache
    • Small number Instructions
      • They are optimized for quick execution
### Reduced Instruction Set Computer – RISC

#### Key aspects
- Small number Instructions

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<th>Data Movement</th>
<th>Arithmetic</th>
<th>Logical</th>
<th>Bit and Bit Field</th>
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<td>Load, Store, Move, Load Address</td>
<td>Add, Subtract, Multiply, Divide, Remainder, Modulo, Shift, Extended Multiply, Extended Divide</td>
<td>And, Not And, And Not, Or, Exclusive Or, Not Or, Or Not, Nor, Exclusive Nor, Not, Nand, Rotate</td>
<td>Set Bit, Clear Bit, Not Bit, Check Bit, Alter Bit, Scan For Bit, Scan Over Bit, Extract, Modify</td>
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<th>Call/Return</th>
<th>Fault</th>
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<td>Compare, Conditional Compare, Compare and Increment, Compare and Decrement</td>
<td>Unconditional Branch, Conditional Branch, Compare and Branch</td>
<td>Call, Call Extended, Call System, Return, Branch and Link</td>
<td>Conditional Fault, Synchronize Faults</td>
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<table>
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<tr>
<th>Debug</th>
<th>Miscellaneous</th>
<th>Decimal</th>
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<tr>
<td>Modify Trace Controls, Mark, Force Mark</td>
<td>Atomic Add, Atomic Modify, Flush Local Registers, Modify Arithmetic Controls, Scan Byte for Equal, Test Condition Code</td>
<td>Move, Add with Carry, Subtract with Carry</td>
</tr>
</tbody>
</table>

### Synchronous
- Synchronous Load
- Synchronous Move
Embedded Slot Machine RISC with μP Parallel Command Execution

- Reduced Instruction Set Computer – RISC
- Key aspects – Package Pin-out

Figure 16. 84-Lead Plastic Leaded Chip Carrier (PLCC) Package
Embedded Slot Machine RISC with μP Parallel Command Execution

- Reduced Instruction Set Computer – RISC
- Key aspects – Sample of control signal timing for 80960

![Non-Burst Read and Write Transactions Without Wait States](image1.png)

![Interrupt Acknowledge Cycle](image2.png)
S-Plus Slot Machine Block Diagram
S-Plus Slot Machine Block Diagram

• Major Subsystems
  • List of Internal Subsystems
    • Door Assembly
    • Mother Board
    • CPU Board
    • Power Supply and Line Filters
    • Printers, validators, meters
    • Reels
    • Connection to Progressive systems
  • List of External Systems
    • Some type of slot data system
    • Some type of Player tracking system

• Door Assembly
  • Power connections
    • 110VAC for Upper and Lower Fluorescent Assemblies
S-Plus Slot Machine Block Diagram

• Door Assembly
  • Major Input Devices
    • Player Panel Switches
    • Door Optic Sensors
    • Maybe Coin comparator and other coin sensors
    • Motherboard connections: J1, J2, & J3
  • Major Output Devices
    • Win Display
    • Credit Display
    • Coins/Credits In display
    • Maybe a Coin Diverter Mechanism
    • Motherboard connections: J1 & J2
S-Plus Slot Machine Block Diagram

- **Mother Board**
  - **Overview**
    - Not like PC Mother Boards
      - Just a back plane
      - μP and memory on the plug-in CPU board
    - Major interconnection point for internal and external devices
S-Plus Slot Machine Block Diagram

• **Power Supply**
  • **Overview**
  • Line Filters
    • Protect the power supply and Slot Machine from dirty input power
    • Supply clean 110VAC to internal subsystems
      • Flourescent Lights
      • Hopper Motor
  • **Power supply**
    • Provides clean DC voltage at various voltage levels
S-Plus Slot Machine Block Diagram

- **Reels**
  - Provides inputs from the reel optics
  - Stepper motors drive the reels which are an output
  - Connected to J12 on the mother board

- **Slot Handle**
  - Output signals unlock the handle so it can be pulled
  - Sensors indicate when the handle has been pulled and this is an input to the CPU
  - Connected to J10 on the mother board

- **External Slot Data System connection**
  - Mother board connector J9
Players Edge+ Block Diagram
Players Edge+ Block Diagram

- Major Differences with the S-Plus Slot
  - Player’s Edge has a video display for Output and a touch screen for Input
  - The S-Plus uses reels as the major user readable output and it has a slot handle as an input
Vision+ Block Diagram