AetherRISC: Parity Requirements & Extended Feature Set

Project: AetherRISC

Version: 0.0.0 (Pre-Alpha)

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Standard Compliance: IEEE 830-1998 (SRS)

1. Introduction

1.1 Purpose

This document defines the **Extended Feature Set** required to achieve absolute functional parity with legacy educational simulators (Venus, RARS, MARS, and RARS Nova). It serves as the blueprint for the "Compatibility Layer" that ensures seamless migration for institutional users.

1.2 Design Philosophy: "Strict Modularity"

Features are categorized into two tiers to maintain system performance and architectural purity:

1. **Core Modules (Mandatory):** Fundamental assembly parsing logic required for basic operation. These are compiled into AetherRISC.Core but isolated in the Assembler namespace.
2. **Extended Modules (Optional):** Legacy hardware emulation, linters, and specific system call sets. These must be toggleable via SystemConfig and instantiated only when requested.

2. The Macro Assembler Subsystem (Core Module)

AetherRISC implements a multi-pass **Pre-Processing Assembler** responsible for transforming human-readable assembly source into a flat stream of instructions before they reach the Instruction Decoder.

2.1 Directive Support

The assembler supports the GNU Assembler (GAS) standard syntax used by RARS and Venus.

- **Segment Directives:**
  - .text: Sets insertion pointer to Instruction Segment (0x00400000).
  - .data: Sets insertion pointer to Data Segment (0x10010000).

    - .bss: Sets insertion pointer to Uninitialized Data Segment.
- **Data Directives:**
    - .word, .half, .byte: Integer allocation.
    - .asciiz / .string: Null-terminated strings.
    - .space <n>: Zero-filled memory allocation.
    - .align <n>: Aligns the next datum to a 2^n byte boundary.
- **Symbol Directives:**
    - .globl <symbol>: Exports symbol for linking.
    - .eqv <alias>, <val>: Constant definition.
    - .include "filename": (New) Injects contents of another file at the current line.

2.2 Advanced Label Support

- **Local Labels:** Support for numeric labels (1:, 2:) and relative references (1f for forward, 1b for backward). Crucial for compatibility with optimized RARS code.

2.3 Macro Engine

- **Syntax:**
```
.macro %name (%arg1, %arg2)
   # body
.end_macro
```

- **Behavior:** Textual substitution engine running *before* parsing. Supports nested macros.

2.4 Pseudo-Instruction Expansion

Implements the full RISC-V Pseudo-Instruction set as defined by the unprivileged spec.

Pseudo	**Expansion (RV32I)**
li rd, imm	lui + addi (smart expansion based on immediate size)
la rd, label	auipc + addi
mv rd, rs	addi rd, rs, 0
not rd, rs	xori rd, rs, -1
neg rd, rs	sub rd, x0, rs
seqz rd, rs	sltiu rd, rs, 1
snez rd, rs	sltu rd, x0, rs

j label	jal x0, label
call label	auipc + jalr (function call)
tail label	auipc + jalr (tail call optimization)
ret	jalr x0, x1, 0
nop	addi x0, x0, 0

3. Legacy Hardware Emulation (Optional Modules)

These modules simulate specific memory-mapped I/O devices found in older tools. They are loaded dynamically based on the active MmioPreset.

3.1 Preset: RARS Bitmap Display

- **ID:** preset_rars_bitmap
- **Memory Map:** Configurable (Default 0x10010000).
- **Resolution:** Configurable Width/Height (Default 512x512).
- **Pixel Size:** Configurable (Default 8x8).
- **Behavior:**
  - Writes to memory range update an HTML5 Canvas buffer.
  - Supports "Connect to Program" mode (auto-redraw) vs "Manual Redraw."

3.2 Preset: RARS Digital Lab Sim

- **ID:** preset_rars_digilab
- **Memory Map:** Fixed 0xFFFF0010 - 0xFFFF0014.
- **Components:**
  - **Hex Keypad:** Writes nibbles to 0xFFFF0012 on click.
  - **7-Segment Displays:** Two displays bound to 0xFFFF0010 (Left) and 0xFFFF0011 (Right).
  - **Interrupts:** Supports the original RARS interrupt generation logic when keys are pressed.

3.3 Preset: RARS Nova (Extended IO)

- **ID:** preset_rars_nova
- **Components:**
  - **MIDI Out:** Maps specific addresses to the browser's WebAudio API to play synthesized notes (Legacy MARS syscall parity).
  - **File Dialogs:** specific MMIO triggers that open the host OS file picker.

4. Static Analysis & Linting (Optional Modules)

The StaticAnalyzer service runs analysis passes on the parsed AST.

4.1 "Venus Strict" Mode

- **Enforce Calling Convention:** Warns on modification of s0-s11 without stack preservation.
- **Enforce Stack Alignment:** Errors if sp is not 16-byte aligned at function calls (standard RISC-V requirement).
- **Dead Code Detection:** Warns about code following unconditional jumps that lacks a label.

4.2 "RARS Relaxed" Mode

- Disables alignment checks.
- Permits modification of reserved registers (gp, tp) without warnings (common in embedded kernels).

5. System Call Parity Layers

The SyscallManager supports swappable "Personalities."

5.1 Personality: Venus/RARS (Default)

Implements the union of all syscalls from both tools.

ID	Name	Description
1	PrintInt	Prints integer in a0 to console.
4	PrintString	Prints string at address a0.
5	ReadInt	Reads int from console into a0.
8	ReadString	Reads string into buffer a0.
9	Sbrk	Allocates heap memory.
10	Exit	Terminates program.
17	Exit2	Terminates with error code.
30	Time	Returns milliseconds since

		epoch (64-bit).
31	MidiOut	Plays MIDI note (RARS extension).
50	MessageDialog	Opens alert box (RARS extension).
57-62	FileIO	Open, Read, Write, Close, Lseek.

6. Collaboration & Headless Operation

6.1 "Venus Link" (Permalink System)

- **URL Structure:** https://sim.aetherrisc.com/#code=<Base64_LZ_String>
- **Function:** Instantly loads environment and code from URL.
- **Parity:** Compatible with Venus link decoding algorithms.

6.2 Headless Grading API

To support automated grading of student assignments via CI/CD (GitHub Actions/Gradescope).

- **CLI Tool:** AetherRISC.CLI
- **Usage:**
  aether-cli run solution.s --input inputs.txt --assert-reg a0=120 --max-cycles 1000

- **Output:** JSON formatted report (Pass/Fail, Cycle Count, Register Dump).

7. Configuration Schema (parity_config.json)

```
{
  "assembler": {
    "dialect": "gnu", // "gnu" or "legacy_mars"
    "allow_pseudo_ops": true,
    "macros_enabled": true
  },
  "simulation": {
    "ecall_personality": "venus_rars_hybrid", // "venus", "rars", "spike_pk"
    "mmio_preset": "preset_rars_bitmap",
    "random_seed": 42 // For deterministic "random" syscalls
  },
  "linter": {
```

```
    "strict_calling_convention": false,
    "warn_on_register_alias": true // e.g., warn if using x10 instead of a0
  }
}
```