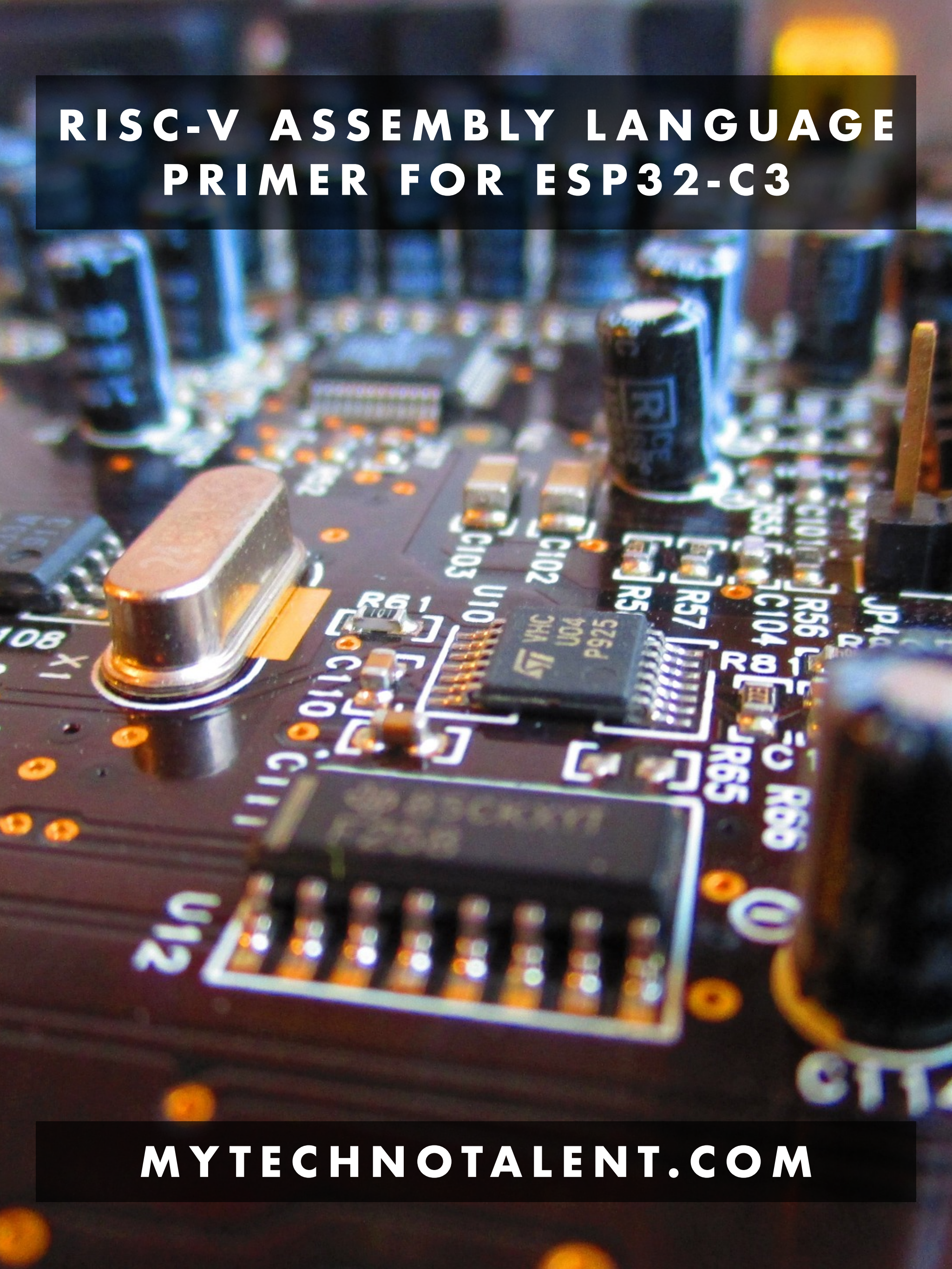
RISC-V ASSEMBLY LANGUAGE PRIMER FOR ESP32-C3



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Introduction

This primer is designed to give you a foundational understanding of RISC-V assembly language, focusing on the ESP32-C3 microcontroller. By the end of this guide, you'll have a grasp of the core architecture, key registers, and essential assembly instructions needed to start writing your own RISC-V programs.

ESP32-C3 Architecture Overview

The ESP32-C3 is based on the RISC-V architecture, a streamlined and open-source instruction set. The key components of the ESP32-C3 architecture include 32 general-purpose registers, the Program Counter (PC), and several special-purpose registers.

Key Registers

- **ra** (Return Address): Holds the return address for subroutines.

- **sp** (Stack Pointer): Points to the current top of the stack.

- **gp** (Global Pointer): Points to the global data section.

- **tp** (Thread Pointer): Points to the current thread context.

- **t0-t6** (Temporary Registers): Used for temporary data that is not preserved across function calls.

- **fp/s0** (Frame Pointer): Points to the base of the current stack frame.

- **s1-s11** (Saved Registers): Used to preserve data across function calls.

- **a0-a7** (Argument Registers): Used to pass arguments to functions and return values.

- **pc** (Program Counter): Holds the address of the current instruction being executed.

Loading and Storing Words

- **lw rd, offset(rs1)**: Load a word from memory into register *rd*.

```
lw t0, 0(sp)  # Load word from memory at addr in sp, offset 0 to t0
```

- **sw rs2, offset(rs1)**: Store a word from register *rs2* into memory.

```
sw t0, 4(sp)  # Store word in t0 to memory at address sp + 4
```

Arithmetic Operations

- **add rd, rs1, rs2**: Add *rs1* and *rs2*, store the result in *rd*.

```
add t0, t1, t2  # t0 = t1 + t2
```

- **sub rd, rs1, rs2**: Subtract *rs2* from *rs1*, store the result in *rd*.

```
sub t0, t1, t2  # t0 = t1 - t2
```

- **mul rd, rs1, rs2**: Multiply *rs1* and *rs2*, store the result in *rd*.

```
mul t0, t1, t2  # t0 = t1 * t2
```

- **div rd, rs1, rs2**: Divide *rs1* by *rs2*, store the result in *rd*.

```
div t0, t1, t2  # t0 = t1 / t2
```

Control Flow

- **beq rs1, rs2, label**: Branch to *label* if *rs1* equals *rs2*.

```
beq t0, t1, loop  # If t0 == t1, jump to loop
```

- **j label**: Unconditional jump to *label*.

```
j end  # Jump to end
```

Subroutines

- **a0-a7:** Argument registers (used to pass args to subroutines).
- **t0-t6:** Temp registers (not preserved and used within subroutines).
- **ra**: Return address (used to return to the caller)

```
.global add_numbers


    # Populate args
    li a0, 42
    li a1, 1
add_numbers:
    # Add the contents of a0 and a1, store result in a0
    add a0, a0, a1

    # Return from subroutine
    ret
```

Technical Reference Document

- Learn more about the ESP32-C3 here!
  - **https://www.espressif.com/sites/default/files/documentation/esp32-c3_technical_reference_manual_en.pdf**

Example: Hello World in RISC-V Assembly

Below is a minimal example of using RISC-V assembly within a PlatformIO project to create a simple "Hello World" program.

```
void setup() {
  Serial.begin(115200);
  app_main();
}

void loop() {
}

void app_main() {
  int a0_val;
  asm volatile (
    "li a0, 42 \n"
    "mv %[val], a0 \n"
    : [val] "=r" (a0_val)
  );

  printf("Register a0: %d\n", a0_val);
}
```

Conclusion

This primer has introduced you to the core concepts and instructions of RISC-V assembly for the ESP32-C3 microcontroller. With this foundation, you're now equipped to explore more advanced topics and create more complex programs using RISC-V assembly.

You can live test the above example and hack it to try the other instructions that were introduced.

https://wokwi.com/projects/406420597062574081

If you are interested in a deeper dive into RISC-V Assembler, please visit the below link.

https://github.com/mytechnotalent/Hacking-RISC-V