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# **RISC-V Configuration Validator Documentation**

*Release [2.15.1]*

**InCore Semiconductors Pvt. Ltd.**

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## INTRODUCTION

**RISCV-Config** (RISCV Configuration Leagalizer) is a YAML based framework which can be used to validate the specifications of a RISC-V implementation against the RISC-V privileged and unprivileged ISA spec and generate standard specification yaml file.

**Caution:** This is still a work in progress and non-backward compatible changes are expected to happen.

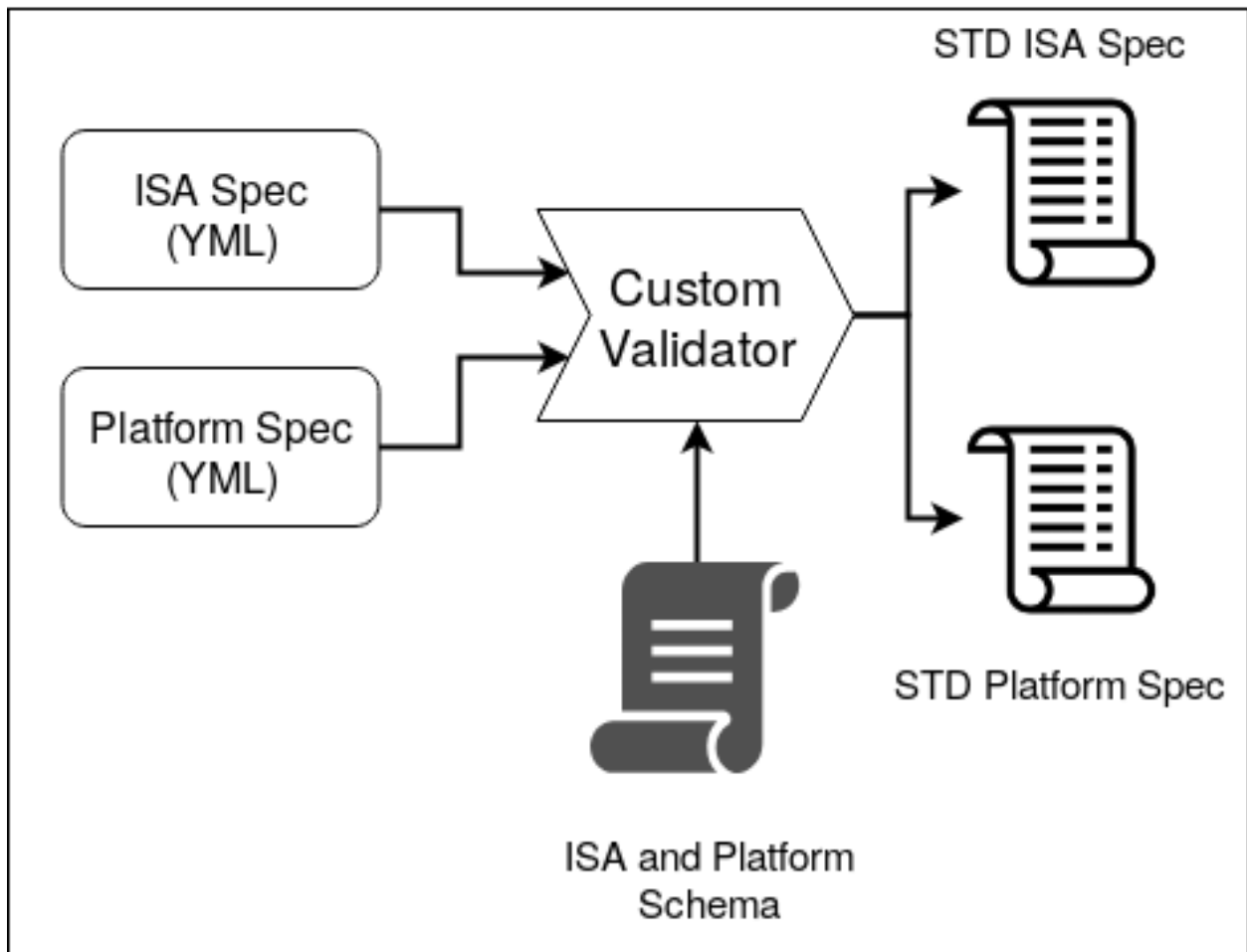
For more information on the official RISC-V spec please visit: [RISC-V Specs](#)

RISCV-Config [[Repository](#)]



## OVERVIEW

The following diagram captures the overall-flow of RISC-V-Config.



The user is required to provide 2 YAML files as input:

1. **ISA Spec:** This YAML file is meant to capture the ISA related features implemented by the user. Details of this input file can be found here : [ISA YAML Spec](#).
2. **Platform Spec:** This YAML file is meant to capture the platform specific features implemented by the user. Details of this input file can be found here : [Platform YAML Spec](#).

## 2.1 Working

The ISA and Platform spec are first checked by the validator for any inconsistencies. Checks like 'F' to exist for 'D' are performed by the validator. The validator exits with an error if any illegal configuration for the spec is provided. Once the validator checks pass, two separate standard yaml files are generated, one for each input type. These standard yaml files contain all fields elaborated and additional info for each node. While the user need not specify all the fields in the input yaml files, the validator will assign defaults to those fields and generate a standard exhaustive yaml for both ISA and Platform spec.



## QUICKSTART

This doc is meant to serve as a quick-guide to setup RISC-V-CONFIG and perform a sample validation of target specifications.

### 3.1 Install Python

RISC-V-CONFIG requires *pip* and *python* ( $\geq 3.6$ ) to be available on your system.

#### 3.1.1 Ubuntu

Ubuntu 17.10 and 18.04 by default come with *python-3.6.9* which is sufficient for using *riscv-config*.

If you are on Ubuntu 16.10 and 17.04 you can directly install *python3.6* using the Universe repository:

```
$ sudo apt-get install python3.6
$ pip3 install --upgrade pip
```

If you are using Ubuntu 14.04 or 16.04 you need to get *python3.6* from a Personal Package Archive (PPA):

```
$ sudo add-apt-repository ppa:deadsnakes/ppa
$ sudo apt-get update
$ sudo apt-get install python3.6 -y
$ pip3 install --upgrade pip
```

You should now have 2 binaries: *python3* and *pip3* available in your *\$PATH*. You can check the versions as below:

```
$ python3 --version
Python 3.6.9
$ pip3 --version
pip 20.1 from <user-path>.local/lib/python3.6/site-packages/pip (python 3.6)
```

### 3.1.2 Centos:7

The CentOS 7 Linux distribution includes Python 2 by default. However, as of CentOS 7.7, Python 3 is available in the base package repository which can be installed using the following commands:

```
$ sudo yum update -y
$ sudo yum install -y python3
$ pip3 install --upgrade pip
```

For versions prior to 7.7 you can install python3.6 using third-party repositories, such as the IUS repository:

```
$ sudo yum update -y
$ sudo yum install yum-utils
$ sudo yum install https://centos7.iuscommunity.org/ius-release.rpm
$ sudo yum install python36u
$ pip3 install --upgrade pip
```

You can check the versions:

```
$ python3 --version
Python 3.6.8
$ pip --version
pip 20.1 from <user-path>.local/lib/python3.6/site-packages/pip (python 3.6)
```

### 3.1.3 Using Virtualenv for Python

Many a times folks face issues in installing and managing python versions, which is actually a major issue as many gui elements in Linux use the default python versions. In which case installing python3.6 using the above methods might break other software. We thus advise the use of **pyenv** to install python3.6.

For Ubuntu and CentosOS, please follow the steps here: <https://github.com/pyenv/pyenv#basic-github-checkout>

RHEL users can find more detailed guides for virtual-env here: <https://developers.redhat.com/blog/2018/08/13/install-python3-rhel/#create-env>

Once you have pyenv installed do the following to install python 3.6.0:

```
$ pyenv install 3.6.0
$ pip3 install --upgrade pip
$ pyenv shell 3.6.0
```

You can check the version in the **same shell**:

```
$ python --version
Python 3.6.0
$ pip --version
pip 20.1 from <user-path>.local/lib/python3.6/site-packages/pip (python 3.6)
```

## 3.2 Install RISC-V CONFIG

**Note:** If you are using a virtual environment make sure to enable that environment before performing the following steps.

```
$ pip3 install riscv_config
```

To update an already installed version of RISC-V CONFIG to the latest version:

```
$ pip3 install -U riscv_config
```

To checkout a specific version of `riscv_config`:

```
$ pip3 install riscv_config==1.x.x
```

Once you have RISC-V CONFIG installed, executing `riscv_config --help` should print the following output

```
riscv_config [-h] [--version] [--isa_spec YAML] [--platform_spec YAML]
              [--work_dir DIR] [--verbose]

RISC-V Configuration Validator

optional arguments:
  --isa_spec YAML, -ispec YAML
                        The YAML which contains the ISA specs.
  --platform_spec YAML, -pspec YAML
                        The YAML which contains the Platform specs.
  --verbose
                        debug | info | warning | error
  --version, -v
                        Print version of RISC-V CONFIG being used
  --work_dir DIR
                        The name of the work dir to dump the output files to.
  -h, --help
                        show this help message and exit
```

## 3.3 RISC-V CONFIG for Developers

Clone the repository from git and install required dependencies.

**Note:** you will still need python (>=3.6.0) and pip. If you are using `pyenv` as mentioned above, make sure to enable that environment before performing the following steps.

```
$ git clone https://github.com/riscv/riscv-config.git
$ cd riscv_config
$ pip3 install -r requirements.txt
```

Executing `python -m riscv_config.main --help` should display the same help message as above.

## 3.4 Usage Example

```
$ riscv-config -ispec examples/rv32i_isa.yaml -pspec examples/rv32i_platform.yaml
```

Executing the above command should display the following on the terminal:

```
[INFO]      : Input-ISA file
[INFO]      : Loading input file: /scratch/git-repo/github/riscv-config/examples/rv32i_
↪isa.yaml
[INFO]      : Load Schema /scratch/git-repo/github/riscv-config/riscv_config/schemas/
↪schema_isa.yaml
[INFO]      : Initiating Validation
[INFO]      : No Syntax errors in Input ISA Yaml. :)
[INFO]      : Initiating post processing and reset value checks.
[INFO]      : Dumping out Normalized Checked YAML: /scratch/git-repo/github/riscv-
↪config/riscv_config_work/rv32i_isa_checked.yaml
[INFO]      : Input-Platform file
[INFO]      : Loading input file: /scratch/git-repo/github/riscv-config/examples/rv32i_
↪platform.yaml
[INFO]      : Load Schema /scratch/git-repo/github/riscv-config/riscv_config/schemas/
↪schema_platform.yaml
[INFO]      : Initiating Validation
[INFO]      : No Syntax errors in Input Platform Yaml. :)
[INFO]      : Dumping out Normalized Checked YAML: /scratch/git-repo/github/riscv-
↪config/riscv_config_work/rv32i_platform_checked.yaml
```

## YAML SPECIFICATIONS

This section provides details of the ISA and Platform spec YAML files that need to be provided by the user.

### 4.1 ISA YAML Spec

**NOTE:**

1. All integer fields accept values as integers or hexadecimals(can be used interchangeably) unless specified otherwise.
2. Different examples of the input yamls and the generated checked YAMLS can be found here : [Examples](#)

#### 4.1.1 Vendor

**Description:** Vendor name.

**Examples:**

```
Vendor: Shakti
Vendor: Incoresemi
```

#### 4.1.2 Device

**Description:** Device Name.

**Examples:**

```
Device: E-Class
Device: C-Class
```

**Constraints:**

- None

### 4.1.3 ISA

**Description:** Takes input a string representing the ISA supported by the implementation. All extension names (other than Zext) should be mentioned in upper-case. Z extensions should begin with an upper-case 'Z' followed by lower-case extension name (without Camel casing)

**Examples:**

```
ISA: RV32IMA
ISA: RV64IMAFDCZifencei
```

**Constraints:**

- Certain extensions are only valid in certain user-spec version. For, eg. Zifencei is available only in user-spec 2.3 and above.
- The ISA string must be specified as per the convention mentioned in the specifications (like subsequent Z extensions must be separated with an '\_' )

### 4.1.4 User\_Spec\_Version

**Description:** Version number of User/Non-privileged ISA specification as string. Please enclose the version in "" to avoid type mismatches.

**Examples:**

```
User_Spec_Version: "2.2"
User_Spec_Version: "2.3"
```

**Constraints:**

- should be a valid version later than 2.2

### 4.1.5 Privilege\_Spec\_Version

**Description:** Version number of Privileged ISA specification as string. Please enclose the version in "" to avoid type mismatches.

**Examples:**

```
Privilege_Spec_Version: "1.10"
Privilege_Spec_Version: "1.11"
```

**Constraints:**

- should be a valid version later than 1.10

### 4.1.6 hw\_data\_misaligned\_support

**Description:** A boolean value indicating whether hardware support for misaligned load/store requests exists.

**Examples:**

```
hw_data_misaligned_support: True
hw_data_misaligned_support: False
```

**Constraints:**

- None

### 4.1.7 supported\_xlen

**Description:** list of supported xlen on the target

**Examples:**

```
supported_xlen : [32]
supported_xlen : [64, 32]
supported_xlen : [64]
```

**Constraints:**

- None

### 4.1.8 pmp\_granularity

**Description:** Granularity of pmps

**Examples:**

```
pmp_granularity : 2
pmp_granularity : 4
```

**Constraints:**

- None

### 4.1.9 physical\_addr\_sz

**Description:** size of the physical address

**Examples:**

```
physical_addr_sz : 32
```

**Constraints:**

- None

### 4.1.10 custom\_exceptions

**Description:** list of custom exceptions implemented

**Examples:**

```
custom_exceptions:
- cause_val: 25
  cause_name: mycustom
- cause_val: 26
  cause_name: mycustom2
```

**Constraints:**

- None

### 4.1.11 custom\_interrupts

**Description:** list of custom interrupts implemented

**Examples:**

```
custom_interrupts:
- cause_val: 25
  cause_name: mycustom
- cause_val: 26
  cause_name: mycustom2
```

**Constraints:**

- None

## 4.2 CSR Template

All csrs are defined using a common template. Two variants are available: csrs with subfields and those without

### 4.2.1 CSRs with sub-fields

```
<name>: # name of the csr
description: <text> # textual description of the csr
address: <hex> # address of the CSR
priv_mode: <D/M/H/S/U> # privilege mode that owns the register
reset-val: <hex> # Reset value of the register. This an_
↳accumulation # of the all reset values of the sub-fields
rv32: # this node and its subsequent fields can_
↳exist # if [M/S/U]XL value can be 1
accessible: <boolean> # indicates if the csr is accessible in_
↳rv32 mode or not. # When False, all fields below will be_
↳trimmed off # in the checked yaml. False also indicates_
↳that
```

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```

fields: # access-exception should be generated.
↳of the # a quick summary of the list of all fields.
# csr including a list of WPRI fields of
↳the csr.
  - <field_name1>
  - <field_name2>
  - - [23,30] # A list which contains a squashed pair
  - 6 # (of form [lsb,msb]) of all WPRI bits.
↳within the # csr. Does not exist if there are no WPRI
↳bits
  <field_name1>: # name of the field
    description: <text> # textual description of the csr
    shadow: <csr-name>::<field> # which this field shadows, 'none' indicates
↳that # this field does not shadow anything.
    msb: <integer> # msb index of the field. max: 31, min:0
    lsb: <integer> # lsb index of the field. max: 31, min:0
    implemented: <boolean> # indicates if the user has implemented
↳this field # or not. When False, all
# fields below this will be trimmed.
type: # type of field. Can be only one of the
↳following
  wrl1: [list of value-descriptors] # field is wrl1 and the set of legal values.
  ro_constant: <hex> # field is readonly and will return the
↳same value.
  ro_variable: True # field is readonly but the value returned
↳depends # on other arch-states
  warl: # field is warl type. Refer to WARL section
    dependency_fields: [list]
    legal: [list of warl-string]
    wr_illegal: [list of warl-string]
  rv64: # this node and its subsequent fields can
↳exist # if [M/S/U]XL value can be 2
  accessible: <boolean> # indicates if this register exists in rv64
↳mode # or not. Same definition as for rv32 node.
  rv128: # this node and its subsequent fields can
↳exist if # [M/S/U]XL value can be 3
  accessible: <boolean> # indicates if this register exists in
↳rv128 mode # or not. Same definition as for rv32 node.

```

## 4.2.2 CSRs without sub-fields

```

<name>: # name of the csr
  description: <text> # textual description of the csr
  address: <hex> # address of the CSR
  priv_mode: <D/M/H/S/U> # privilege mode that owns the register
  reset-val: <hex> # Reset value of the register. This an_
↳accumulation # of the all reset values of the sub-fields
  rv32: # this node and its subsequent fields can_
↳exist # if [M/S/U]XL value can be 1
  accessible: <boolean> # indicates if the csr is accessible in rv32_
↳mode or not. # When False, all fields below will be_
↳trimmed off # in the checked yaml. False also indicates_
↳that # access-exception should be generated
  fields: [] # This should be empty always.
  shadow: <csr-name>::<register> # which this register shadows, 'none'_
↳indicates that # this register does not shadow anything.
  msb: <int> # msb index of the csr. max: 31, min:0
  lsb: <int> # lsb index of the csr. max: 31, min:0
  type: # type of field. Can be only one of the_
↳following
  wrl: [list of value-descriptors] # field is wrl and the set of legal values.
  ro_constant: <hex> # field is readonly and will return the same_
↳value.
  ro_variable: True # field is readonly but the value returned_
↳depends # on other arch-states
  warl: # field is warl type. Refer to WARL section
  dependency_fields: [list]
  legal: [list of warl-string]
  wr_illegal: [list of warl-string]
  rv64: # this node and its subsequent fields can_
↳exist # if [M/S/U]XL value can be 2
  accessible: <boolean> # indicates if this register exists in rv64_
↳mode # or not. Same definition as for rv32 node.
  rv128: # this node and its subsequent fields can_
↳exist if # [M/S/U]XL value can be 3
  accessible: <boolean> # indicates if this register exists in rv128_
↳mode

```

### 4.2.3 Constraints

Each CSR undergoes the following checks:

1. All implemented fields at the csr-level, if set to True, are checked if they comply with the supported\_xlen field of the ISA yaml.
2. The reset-val is checked against compliance with the type field specified by the user. All unimplemented fields are considered to be hardwired to 0.

For each of the above templates the following fields for all standard CSRs defined by the spec are frozen and **CANNOT** be modified by the user.

- description
- address
- priv\_mode
- fields
- shadow
- msb
- lsb
- The type field for certain CSRs (like readonly) is also constrained.
- fields names also cannot be modified for standard CSRs

Only the following fields can be modified by the user:

- reset-value
- type
- implemented

### 4.2.4 Example

Following is an example of how a user can define the mtvec csr in the input ISA YAML for a 32-bit core:

```
mtvec:
reset-val: 0x80010000
rv32:
  accessible: true
  base:
    implemented: true
    type:
      wr1:
        dependency_fields: [mtvec::mode]
        legal:
          - "mode[1:0] in [0] -> base[29:0] in [0x20000000, 0x20004000]"
↔# can take only 2 fixed values in direct mode.
          - "mode[1:0] in [1] -> base[29:6] in [0x000000:0xF00000] base[5:0] in [0x00]"
↔" # 256 byte aligned values only in vectored mode.
        wr_illegal:
          - "mode[1:0] in [0] -> Unchanged"
          - "mode[1:0] in [1] and wr_val in [0x2000000:0x4000000] -> 0x2000000"
          - "mode[1:0] in [1] and wr_val in [0x4000001:0x3FFFFFFF] -> Unchanged"
      mode:
```

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```
implemented: true
type:
  warl:
    dependency_fields: []
    legal:
      - "mode[1:0] in [0x0:0x1] # Range of 0 to 1 (inclusive)"
    wr_illegal:
      - "Unchanged"
```

The following is what the riscv-config will output after performing relevant checks on the above user-input:

```
mtvec:
  description: MXLEN-bit read/write register that holds trap vector configuration.
  address: 773
  priv_mode: M
  reset-val: 0x80010000
  rv32:
    accessible: true
    base:
      implemented: true
      type:
        warl:
          dependency_fields: [mtvec::mode]
          legal:
            - 'mode[1:0] in [0] -> base[29:0] in [0x20000000, 0x20004000]'
            ↪ # can take only 2 fixed values in direct mode.
            - 'mode[1:0] in [1] -> base[29:6] in [0x000000:0xF00000] base[5:0] in [0x00]
            ↪' # 256 byte aligned values only in vectored mode.
          wr_illegal:
            - 'mode[1:0] in [0] -> Unchanged'
            - 'mode[1:0] in [1] and wr_val in [0x2000000:0x4000000] -> 0x2000000'
            - 'mode[1:0] in [1] and wr_val in [0x4000001:0x3FFFFFFF] -> Unchanged'
        description: Vector base address.
      shadow: none
      msb: 31
      lsb: 2
    mode:
      implemented: true
      type:
        warl:
          dependency_fields: []
          legal:
            - 'mode[1:0] in [0x0:0x1] # Range of 0 to 1 (inclusive)'
          wr_illegal:
            - Unchanged

      description: Vector mode.
      shadow: none
      msb: 1
      lsb: 0
      fields:
        - mode
        - base
  rv64:
    accessible: false
```

## 4.3 WARL field Definition

Since the RISC-V privilege spec indicates several CSRs and sub-fields of CSRs to be WARL (Write-Any-Read-Legal), it is necessary to provide a common scheme of representation which can precisely define the functionality of any such WARL field/register.

### 4.3.1 Value Descriptors

This is a list which describes a set of values. Each entry can either represent a single distinct value or a range of values.

- **distinct-values** - This specifies that only the particular value should be added to the set.

```
val
```

- **range** - This specifies that all the values greater than or equal to lower and less than or equal to upper is to be included in the set.

```
lower:upper
```

Example:

```
# To represent the set {0, 1, 2, 3, 4, 5}
[0:5]

# To represent the set {5, 10, 31}
[5, 10, 31]

# To represent the set {2, 3, 4, 5, 10}
[2:5, 10]
```

### 4.3.2 WARL Node definition

A WARL csr/field has the following skeleton in the riscv-config:

```
WARL:
  dependency_fields: [list]
  legal: [list of warl-string]
  wr_illegal: [list of warl-string]
```

- **dependency\_fields** : A list of other csrs/fields whose values define the set of legal values the csr/field under question can take. We use :: as a hierarchy separator. This field can be empty as well indicating no other state affects this csr/field. The fields within csrs can be specified as follows:

```
- dependency_fields: [mivec::mode]
- dependency_fields: [misa::mxl, mepc]
```

- **legal** : This field takes in a list of strings which define the WARL functions. Each string needs to adhere to the following syntax:

```
- [dependency-vals] -> field-name[index-hi:index-lo] in [legal-values]
- [dependency-vals] -> field-name[index-hi:index-lo] bitmask [mask, fixedval]

# if no dependency_fields exists then following is also allowed:
```

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```
field-name[index-hi:index-lo] bitmask [mask, fixedval]
```

In short it means that under certain values of the `dependency_fields` the warl-field can take only the legal values defined by either `[legal-values]` or by the `bitmask` function.

- **dependency-vals** : A comma separated list of value-descriptors indicating the values the corresponding fields in the `dependency_fields` take.
- **->**: represents “imply”.
- **field-name**: should be the same as the `csr/field-name` for which this WARL function is being described.
- **index-**: These are unsigned integers not exceeding the size of field. Sometimes it easier to define the WARL function by splitting the fields. Thus the following is also a legal form:

```
[dependency-vals] -> field-name[index-hi:index-lo] in [legal-values1] & field-  
↪name[index-lo-1:0] in [legal-values2]
```

- **in**: key-word indicating that `field-name[index-hi:index-lo]` should takes values defined within `[legal_values]`.
- **bitmask**: keyword indicating that the legal values are defined using a mask and fixedval variables. The fixedval variable defines the default value of the masked bits.
- **legal-values**: a list of value-descriptors indicating the set of legal values `field-name[index-hi:index-lo]` can take.

#### Restrictions:

1. No legal value must exceed the maximum value which can be supported (based on the width of the field).
2. Functions should be exhaustive with respect to every possible combination of the dependency values.
3. within a string for `legal` all bits of the `csr/field` should be covered. No bits must be left undefined.
4. A legal string should be a combination of ranges split into parts or a simple bitmask function for the entire field. Mixing bitmask and ranges is not allowed. The following example is an invalid spec:

```
[0] -> field[31:6] in [0x10000000: 0x3FFFFFF] & field[5:0] bitmask [0x30,  
↪0x0F]
```

- **wr\_illegal** : This field takes in a list of strings which define the next legal value of the field when an illegal value is written. Each string needs to adhere to the following syntax:

```
[dependency-vals] wr_val in [illegal-values] -> update_mode  
OR  
[dependency-vals] -> update_mode
```

In short this means that under certain values of the `dependency_fields` when an illegal write happens (either defined by the `wr_val` or for all illegal values) the next legal value is defined by the `update_mode`.

- **dependency-vals** : A comma separated list of value-descriptors indicating the values the corresponding fields in the `dependency_fields` take.
- **wr\_val**: key-word indicating the illegal write-value
- **in**: same meaning as the before.
- **illegal-values**: a list of value-descriptors indicating the set of illegal values for the `csr/field` under question.

- **update\_mode** : This field dictates what the next legal read value is when an illegal write happens:
  - \* **unchanged**: The value remains unchanged to the current legal value.
  - \* **<val>**: A single value can also be specified
  - \* **nextup**: ceiling(*wr\_val*) i.e. the next larger or the largest element of the legal list
  - \* **nextdown**: floor(*wr\_val*) i.e. the next smallest or the smallest element of the legal list
  - \* **nearup**: ceiling(*wr\_val*) i.e. the closest element in the list, with the larger element being chosen in case of a tie.
  - \* **neardown**: floor(*wr\_val*) i.e. the closes element in the list, with the smaller element being chosen in case of a tie
  - \* **max**: maximum of all legal values
  - \* **min**: minimum of all legal values
  - \* **addr**:

```
if ( val < base || val > bound)
    return Flip-MSB of field
```

#### Restrictions:

1. `wr_illegal` will not exists for a legal list defined as a bitmask.

Example:

```
# When base of mtvec depends on the mode field.
WARL:
  dependency_fields: [mtvec::mode]
  legal:
    - "[0] -> base[29:0] in [0x20000000, 0x20004000]" # can take only 2 fixed values_
↪when mode==0.
    - "[1] -> base[29:6] in [0x000000:0xF00000] base[5:0] in [0x00]" # 256 byte_
↪aligned when mode==1
  wr_illegal:
    - "[0] -> unchanged"
    - "[1] wr_val in [0x2000000:0x4000000] -> 0x2000000" # predefined value if write_
↪value is
    - "[1] wr_val in [0x4000001:0x3FFFFFFF] -> unchanged"

# When base of mtvec depends on the mode field. Using bitmask instead of range
WARL:
  dependency_fields: [mtvec::mode]
  legal:
    - "[0] -> base[29:0] in [0x20000000, 0x20004000]" # can take only 2 fixed values_
↪when mode==0.
    - "[1] -> base[29:0] bitmask [0x3FFFFFFC0, 0x00000000]" # 256 byte aligned when_
↪mode==1
  wr_illegal:
    - "[0] -> unchanged" # no illegal for bitmask defined legal strings.

# no dependencies. Mode field of mtvec can take only 2 legal values using range-
↪descriptor
WARL:
  dependency_fields:
  legal:
```

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```

- "mode[1:0] in [0x0:0x1] # Range of 0 to 1 (inclusive)"
wr_illegal:
- "0x00"

# no dependencies. using single-value-descriptors
WARL:
dependency_fields:
legal:
- "mode[1:0] in [0x0,0x1] # Range of 0 to 1 (inclusive)"
wr_illegal:
- "0x00"

```

## 4.4 Platform YAML Spec

This section describes each node of the PLATFORM-YAML. For each node, we have identified the fields required from the user and also the various constraints involved.

### 4.4.1 reset

**Description:** Stores the value for the reset vector. It can either be a label or an address.

- label: A string field equal to the label in the assembly code
- address: A value equal to the absolute address where the vector is present

**Examples:**

```

reset:
  label: reset_vector
reset:
  label: 0x80000000

```

### 4.4.2 nmi

**Description:** Stores the value for the nmi vector. It can either be a label or an address.

- label: A string field equal to the label in the assembly code.
- address: A value equal to the absolute address where the vector is present.

**Examples:**

```

nmi:
  label: nmi_vector
nmi:
  address: 0x8000000

```



### 4.4.3 `mtime`

**Description:** Stores the fields for memory mapped `mtime` register.

- `implemented`: A boolean field indicating that the register has been implemented.
- `address`: A value equal to the physical address at which the register is present.

**Examples:**

```
mtime:
  implemented: True
  address: 0x458
```

**Constraints:**

- None

### 4.4.4 `mtimecmp`

**Description:** Stores the fields for memory mapped `mtimecmp` register.

- `implemented`: A boolean field indicating that the register has been implemented.
- `address`: A value equal to the physical address at which the register is present.

**Examples:**

```
mtimecmp:
  implemented: True
  address: 0x458
```

**Constraints:**

- None

### 4.4.5 `mtval_condition_writes`

**Description:** Stores the fields for `mtval_condition_writes` register.

- `implemented`: A Boolean value indicating whether the register is implemented.
- `behaviour`: A dictionary type to specify which of the exceptions modify the `mtval_condition_writes` reg
  - `e0`: A string type describing the behaviour of exception 0.
  - `e1`: A string type describing the behaviour of exception 1.
  - `e2`: A string type describing the behaviour of exception 2.
  - `e3`: A string type describing the behaviour of exception 3.
  - `e4`: A string type describing the behaviour of exception 4.
  - `e5`: A string type describing the behaviour of exception 5.
  - `e6`: A string type describing the behaviour of exception 6.
  - `e7`: A string type describing the behaviour of exception 7.
  - `e8`: A string type describing the behaviour of exception 8.

- e9: A string type describing the behaviour of exception 9.
- e10: A string type describing the behaviour of exception 10.
- e11: A string type describing the behaviour of exception 11.
- e12: A string type describing the behaviour of exception 12.
- e13: A string type describing the behaviour of exception 13.
- e15: A string type describing the behaviour of exception 15.

**Examples:**

```
TBD: Provide a concrete use-case for the above.
```

**Constraints:**

- None

#### 4.4.6 `scause_non_standard`

**Description:** Stores the fields for the *scause* register.

- `implemented`: A boolean field indicating that the register has been implemented.
- `values`: The list of exception values greater than 16 as assumed by the platform as integers.

**Examples:**

```
scause_non_standard:  
  implemented: True  
  value: [16, 17, 20]
```

**Constraints:**

- None

#### 4.4.7 `stval_condition_writes`

**Description:** Stores the fields for *stval\_condition\_writes* register.

- `implemented`: A Boolean value indicating whether the field is implemented.
- `behaviour`: A dictionary type to specify which of the exceptions modify the `stval_condition_writes` reg
  - e0: A string type describing the behaviour of exception 0.
  - e1: A string type describing the behaviour of exception 1.
  - e2: A string type describing the behaviour of exception 2.
  - e3: A string type describing the behaviour of exception 3.
  - e4: A string type describing the behaviour of exception 4.
  - e5: A string type describing the behaviour of exception 5.
  - e6: A string type describing the behaviour of exception 6.
  - e7: A string type describing the behaviour of exception 7.
  - e8: A string type describing the behaviour of exception 8.

- e9: A string type describing the behaviour of exception 9.
- e10: A string type describing the behaviour of exception 10.
- e11: A string type describing the behaviour of exception 11.
- e12: A string type describing the behaviour of exception 12.
- e13: A string type describing the behaviour of exception 13.
- e15: A string type describing the behaviour of exception 15.

**Examples:**

**TBD:** Provide a concrete use-case for the above.

**Constraints:**

- None

### 4.4.8 zicbo\_cache\_block\_sz

**Description:** byte size of the cache block

**Examples:**

```

zicbo_cache_block_sz :
  implemented: true
  zicbom_sz: 64
  zicboz_sz: 64

```

**Constraints:**

- None

## 4.5 Debug YAML Spec

### 4.5.1 supported\_xlen

**Description:** list of supported xlen on the target

**Examples:**

```

supported_xlen : [32]
supported_xlen : [64, 32]
supported_xlen : [64]

```

**Constraints:**

- None

## 4.5.2 Debug\_Spec\_Version

**Description:** Version number of Debug specification as string. Please enclose the version in “” to avoid type mismatches.

**Examples:**

```
Debug_Spec_Version: "1.0.0"  
Debug_Spec_Version: "0.13.2"
```

**Constraints:**

- should be a valid version later than 1.0.0

**debug\_mode Description:** Boolean value indicating if the debug instructions are accessible.

**Examples:**

```
debug_mode: False
```

**parking\_loop Description:** Integer value indicating the address of the debug parking loop

**Examples:**

## ADDING SUPPORT FOR NEW EXTENSIONS

Adding support for a new ISA extension or an adjoining spec to RISC-V CONFIG could entail one or more of the following updates:

1. Updating the ISA string and its constraints to recognize valid configurations of the new extension
2. Updating the `schema_isa.yaml` with new CSRs defined by the new ISA extension
3. Adding new schemas and a new cli argument for supporting adjoining RISC-V specs like debug, trace, etc.

This chapter will describe how one can go about RISC-V achieving the above tasks.

### 5.1 Updates to the ISA string

#### 5.1.1 Modifications in `Schema_isa.yaml`

As shown in the example below, any new extensions and sub extensions have to be enabled by adding them in the regex expression of the `ISA` node. Following is an instance of the node for reference:

```
ISA: { type: string, required: true, check_with: capture_isa_specifics,
      regex: "^
→RV(32|64|128)[IE]+[ABCDEFGFIJKLMNOPQSTUVX]*(Zicsr|Zifencei|Zhintpause|Zam|Ztso|Zkne|Zknd|Zknh|Zkse|Z
→{,1}(_Zicsr){,1}(_Zifencei){,1}(_Zhintpause){,1}(_Zam){,1}(_Ztso){,1}(_Zkne){,1}(_
→Zknd){,1}(_Zknh){,1}(_Zkse){,1}(_Zksh){,1}(_Zkg){,1}(_Zkb){,1}(_Zkr){,1}(_Zks){,1}(_
→Zkn){,1}(_Zbc){,1}(_Zbb){,1}(_Zbp){,1}(_Zbm){,1}(_Zbe){,1}(_Zbf){,1}$"
```

---

**Note:** If you are adding a new Z extension, note that it must be added in 2 places in the regex. The first immediately after the standard extension in the format `|Zgargle`. This is to support that fact that the new Z extension could start immediately after the standard extensions which an underscore. The second will be after the first set of Z extensions in the format `{,1}(_Zgargle)`.

---

## 5.1.2 Adding constraints in the SchemaValidator.py file

While adding a new extension, there can be certain legal and illegal combinations which cannot be easily expressed using the regex above. To facilitate defining illegal conditions, riscv-config allows user to define specific checks via custom python functions.

For the ISA field riscv-config uses the `_check_with_capture_isa_specifics` function to return an error if an illegal combination of the extensions (or subextension) is found.

Following is an example of the constraints imposed by the K extension and its subset. Within the K (Crypto-Scalar extension), subextensions Zkn, Zks, K are supersets of other Zk\* abbreviations. Thus, if the superset extension exists in the ISA, none of the corresponding subset ZK\* should be present in the ISA at the same time.

### Constraints used here :

- 1.If Zkn is present , its subset extensions Zkne, Zknh, Zknd, Zkg and Zkb cannot be present in the ISA string.
- 2.If Zks is present , its subset extensions Zkse, Zksh, Zkg and Zkb cannot be present in the ISA string.
- 3.If K extension is present , its subset extensions Zkn, Zkr, Zkne, Zknh, Zknd, Zkg and Zkb cannot be present in the ISA string.
4. If **B extension** Zbp is present , its subset extensions Zkb cannot be present in the ISA string. Cross-checking across two different extensions can also be done. Zkb contains instructions from other subextensions in B extension like Zbm, Zbe, Zbf and Zbb , but unlike Zbp is not a proper superset.
5. If **B extension** Zbc is present , its subset extensions Zkg cannot be present in the ISA string.

```
(...)
if 'Zkg' in extension_list and 'Zbc' in extension_list:
    self._error(field, "Zkg being a proper subset of Zbc (from B extension) should be
    ↪omitted from the ISA string")
if 'Zkb' in extension_list and 'Zbp' in extension_list :
    self._error(field, "Zkb being a proper subset of Zbp (from B extension) should be
    ↪omitted from the ISA string")
if 'Zks' in extension_list and ( set(['Zkse', 'Zksh', 'Zkg', 'Zkb']) & set(extension_
    ↪list) ):
    self._error(field, "Zks is a superset of Zkse, Zksh, Zkg and Zkb. In presence of
    ↪Zks the subsets must be ignored in the ISA string.")
if 'Zkn' in extension_list and ( set(['Zkne', 'Zknd', 'Zknh', 'Zkg', 'Zkb']) &
    ↪set(extension_list) ):
    self._error(field, "Zkn is a superset of Zkne, Zknd, Zknh, Zkg and Zkb, In
    ↪presence of Zkn the subsets must be ignored in the ISA string")
if 'K' in extension_list and ( set(['Zkn', 'Zkr', 'Zkne', 'Zknd', 'Zknh', 'Zkg', 'Zkb']) &
    ↪set(extension_list) ) :
    self._error(field, "K is a superset of Zkn and Zkr , In presence of K the subsets
    ↪must be ignored in the ISA string")
(...)
```

## 5.2 Assing new CSR definitions

There are two parts to addition of a new csr definition to riscv-config

### 5.2.1 Addition of new csrs to schema

The first step is to add the schema of the new csr in the `schema_isa.yaml` file. Following is an example of how the `stval` csr of the “S” extension is added to the schema.

**Note:** for each csr the user is free to define and re-use existing `check_with` functions to impose further legal conditions. In the example below, the `stval` should only be implemented if the “S” extension in the ISA field is set. This is checked using the `s_check` function. Any new `check_with` functions must be defined in the `schemaValidator.py` file

```
stval:
  type: dict
  schema:
    description:
      type: string
      default: The stval is a warl register that holds the address of the instruction
        which caused the exception.
    address: {type: integer, default: 0x143, allowed: [0x143]}
    priv_mode: {type: string, default: S, allowed: [S]}
    reset-val:
      type: integer
      default: 0
      check_with: max_length
    rv32:
      type: dict
      check_with: s_check
      schema:
        fields: {type: list, default: []}
        shadow: {type: string, default: , nullable: True}
        msb: {type: integer, default: 31, allowed: [31]}
        lsb: {type: integer, default: 0, allowed: [0]}
      type:
        type: dict
        check_with: wr_illegal
        schema: { warl: *ref_warl }
        default:
          warl:
            dependency_fields: []
            legal:
              - stval[31:0] in [0x00000000:0xFFFFFFFF]
            wr_illegal:
              - unchanged

        accessible:
          type: boolean
          default: true
          check_with: rv32_check
      default: {accessible: false}
    rv64:
      type: dict
      check_with: s_check
```

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```

schema:
  fields: {type: list, default: []}
  shadow: {type: string, default: , nullable: True}
  msb: {type: integer, default: 63, allowed: [63]}
  lsb: {type: integer, default: 0, allowed: [0]}
  type:
    type: dict
    check_with: wr_illegal
    schema: { warl: *ref_warl }
    default:
      warl:
        dependency_fields: []
        legal:
          - stval[63:0] in [0x00000000:0xFFFFFFFFFFFFFFFF]
        wr_illegal:
          - unchanged

  accessible:
    default: true
    check_with: rv64_check
  default: {accessible: false}

```

## 5.2.2 Adding default setters in checker.py

The next step in adding a new csr definition is to add its default values. This is done in `checker.py`

Example of adding a default setter for `stval` is shown below. This code basically makes the `stval` csr accessible by default when the “S” extension is enabled in the ISA string.

```
schema_yaml['stval']['default_setter'] = sregsetter
```

```

def sregset():
    '''Function to set defaults based on presence of 'S' extension.'''
    global inp_yaml
    temp = {'rv32': {'accessible': False}, 'rv64': {'accessible': False}}
    if 'S' in inp_yaml['ISA']:
        if 32 in inp_yaml['supported_xlen']:
            temp['rv32']['accessible'] = True
        if 64 in inp_yaml['supported_xlen']:
            temp['rv64']['accessible'] = True
    return temp

```

## 5.3 Adding support for Adjoining RISC-V specs

### 5.3.1 Adding new CLI

For supporting any new adjoining specs, they need to be supplied via a new cli (command line interface) argument. This new argument needs to be added in the to the parser module in `Utils.py` <[https://github.com/riscv/riscv-config/blob/d969b7dc5b2b308bb43b0aa65932fe2e7f8c756c/riscv\\_config/utils.py#L106](https://github.com/riscv/riscv-config/blob/d969b7dc5b2b308bb43b0aa65932fe2e7f8c756c/riscv_config/utils.py#L106)>.

The code below shows an example of how the debug spec is added as an argument to the cli parser module:



```
parser.add_argument('--debug_spec', '-dspec', type=str, metavar='YAML', default=None,
↪help='The YAML which contains the debug csr specs.')
```

### 5.3.2 Adding a new schema

Each new adjoining spec must have a YAML schema defined in the *schemas* <[https://github.com/riscv/riscv-config/tree/master/riscv\\_config/schemas](https://github.com/riscv/riscv-config/tree/master/riscv_config/schemas)> director.

### 5.3.3 Adding checks through checker.py and SchemaValidator.py

The user might want to add more custom checks in checker.py and SchemaValidator.py for the adjoining spec.

For example the check\_debug\_specs() is a function that ensures the isa and debug specifications conform to their schemas. For details on check\_debug\_specs() check here : *riscv\_config.checker*.

Details on the checks like s\_debug\_check() and u\_debug\_check, that can also be added to SchemaValidator.py are here: *riscv\_config.schemaValidator*.

### 5.3.4 Modifications in Constants.py

The new schema must be added in the constants.py to detect its path globally across other files.

```
debug_schema = os.path.join(root, 'schemas/schema_debug.yaml')
```

### 5.3.5 Performing new spec checks

Finally, in the main.py file the user must call the relevant functions from checker.py for validating the inputs against the schema.

```
if args.debug_spec is not None:
    if args.isa_spec is None:
        logger.error('Isa spec missing, Compulsory for debug')
        checker.check_debug_specs(os.path.abspath(args.debug_spec), isa_file, work_dir,
↪True, args.no_anchors)
```



## CODE DOCUMENTATION

### 6.1 riscv\_config.checker

`riscv_config.checker.add_debug_setters` (*schema\_yaml*)

Function to set the default setters for various fields in the debug schema

`riscv_config.checker.add_def_setters` (*schema\_yaml*)

Function to set the default setters for various fields in the schema

`riscv_config.checker.add_reset_setters` (*schema\_yaml*)

Function to set the default setters for extension subfields in the misa

`riscv_config.checker.check_custom_specs` (*custom\_spec*, *work\_dir*, *logging=False*,  
*no\_anchors=False*)

Function to perform ensure that the isa and platform specifications confirm to their schemas. The Cerberus module is used to validate that the specifications confirm to their respective schemas.

#### Parameters

- **isa\_spec** (*str*) – The path to the DUT isa specification yaml file.
- **logging** (*bool*) – A boolean to indicate whether log is to be printed.

**Raises** **ValidationError** – It is raised when the specifications violate the schema rules. It also contains the specific errors in each of the fields.

**Returns** A tuple with the first entry being the absolute path to normalized isa file and the second being the absolute path to the platform spec file.

`riscv_config.checker.check_debug_specs` (*debug\_spec*, *isa\_spec*, *work\_dir*, *logging=False*,  
*no\_anchors=False*)

Function to perform ensure that the isa and debug specifications confirm to their schemas. The Cerberus module is used to validate that the specifications confirm to their respective schemas.

#### Parameters

- **debug\_spec** – The path to the DUT debug specification yaml file.
- **isa\_spec** (*str*) – The path to the DUT isa specification yaml file.
- **logging** (*bool*) – A boolean to indicate whether log is to be printed.

**Raises** **ValidationError** – It is raised when the specifications violate the schema rules. It also contains the specific errors in each of the fields.

**Returns** A tuple with the first entry being the absolute path to normalized isa file and the second being the absolute path to the platform spec file.

`riscv_config.checker.check_isa_specs` (*isa\_spec*, *work\_dir*, *logging=False*,  
*no\_anchors=False*)

Function to perform ensure that the isa and platform specifications confirm to their schemas. The Cerberus module is used to validate that the specifications confirm to their respective schemas.

**Parameters**

- **isa\_spec** (*str*) – The path to the DUT isa specification yaml file.
- **logging** (*bool*) – A boolean to indicate whether log is to be printed.

**Raises ValidationError** – It is raised when the specifications violate the schema rules. It also contains the specific errors in each of the fields.

**Returns** A tuple with the first entry being the absolute path to normalized isa file and the second being the absolute path to the platform spec file.

`riscv_config.checker.check_mhpm` (*spec*, *logging=False*)

Check if the mhpmcounters and corresponding mhpmevents are implemented and of the same size as the source

`riscv_config.checker.check_pmp` (*spec*, *logging=False*)

Check if the mhpmcounters and corresponding mhpmevents are implemented and of the same size as the source

`riscv_config.checker.check_reset_fill_fields` (*spec*, *logging=False*)

The `check_reset_fill_fields` function fills the field node with the names of the sub-fields of the register and then checks whether the reset-value of the register is a legal value. To do so, it iterates over all the subfields and extracts the corresponding field value from the reset-value. Then it checks the legality of the value according to the given field description. If the fields is implemented i.e accessible in both 64 bit and 32 bit modes, the 64 bit mode is given preference.

`riscv_config.checker.check_shadows` (*spec*, *logging=False*)

Check if the shadowed fields are implemented and of the same size as the source

`riscv_config.checker.delegset` ()

Function to set “implemented” value for mideleg regisrer.

`riscv_config.checker.fsset` ()

Function to set defaults based on presence of ‘F’ extension.

`riscv_config.checker.groupc` (*test\_list*)

Generator function to squash consecutive numbers for wpri bits.

`riscv_config.checker.hregset` ()

Function to set defaults based on presence of ‘H’ extension.

`riscv_config.checker.hregseth` ()

Function to set defaults based on presence of ‘H’ extension.

`riscv_config.checker.hset` ()

Function to set defaults based on presence of ‘U’ extension.

`riscv_config.checker.nregset` ()

Function to set defaults based on presence of ‘N’ extension.

`riscv_config.checker.nuset` ()

Function to check and set defaults for all fields which are dependent on the presence of ‘U’ extension and ‘N’ extension.

`riscv_config.checker.reset` ()

Function to set defaults to reset val of misa based on presence of ISA extensions.

`riscv_config.checker.reset_vsstatus` ()

Function to set defaults to reset val of mstatus based on the xlen and S, U extensions

`riscv_config.checker.resetsu()`  
Function to set defaults to reset val of mstatus based on the xlen and S, U extensions

`riscv_config.checker.sregset()`  
Function to set defaults based on presence of 'S' extension.

`riscv_config.checker.sregseth()`  
Function to set defaults based on presence of 'S' extension.

`riscv_config.checker.sset()`  
Function to set defaults based on presence of 'S' extension.

`riscv_config.checker.trim(foo)`  
Function to trim the dictionary. Any node with implemented field set to false is trimmed of all the other nodes.

**Parameters** `foo(dict)` – The dictionary to be trimmed.

**Returns** The trimmed dictionary.

`riscv_config.checker.twset()`  
Function to check and set value for tw field in misa.

`riscv_config.checker.uregset()`  
Function to set defaults based on presence of 'U' extension.

`riscv_config.checker.uregseth()`  
Function to set defaults based on presence of 'U' extension.

`riscv_config.checker.uset()`  
Function to set defaults based on presence of 'U' extension.

## 6.2 riscv\_config.schemaValidator

**class** `riscv_config.schemaValidator.schemaValidator(*args, **kwargs)`  
Custom validator for schema having the custom rules necessary for implementation and checks.

`__init__(*args, **kwargs)`  
The arguments will be treated as with this signature:

`__init__(self, schema=None, ignore_none_values=False, allow_unknown=False, require_all=False, purge_unknown=False, purge_readonly=False, error_handler=errors.BasicErrorHandler)`

`__check_with_cannot_be_false_rv32(field, value)`  
Functions ensures that the field cannot be False in rv32 mode

`__check_with_cannot_be_false_rv64(field, value)`  
Functions ensures that the field cannot be False in rv64 mode

`__check_with_capture_isa_specifics(field, value)`  
Function to extract and store ISA specific information(such as xlen,user spec version and extensions present) and check whether the dependencies in ISA extensions are satisfied.

`__check_with_max_length(field, value)`  
Function to check whether the given value is less than the maximum value that can be stored( $2^{\text{xlen}-1}$ ).

`__check_with_max_length32(field, value)`  
Function to check whether the given value is less than the maximum value that can be stored( $2^{\text{xlen}-1}$ ).

`__check_with_s_debug_check(field, value)`  
Function ensures that the ro\_constant is hardwired to zero when S is present in the ISA string Used mainly for debug schema

`__check_with_u_debug_check` (*field, value*)

Function ensures that the `ro_constant` is hardwired to zero when U is present in the ISA string Used mainly for debug schema

`__check_with_wr_illegal132` (*field, value*)

Function to ensure the `warl` does not cross  $2^{32}$

`__check_with_xcause_check` (*field, value*)

Function to verify the inputs for `mcause`.

`__check_with_xtveccheck` (*field, value*)

Function to check whether the inputs in range type in `mtvec` are valid.

## 6.3 Utils

**class** `riscv_config.utils.ColoredFormatter` (*\*args, \*\*kwargs*)

Class to create a log output which is colored based on level.

`__init__` (*\*args, \*\*kwargs*)

Initialize the formatter with specified format strings.

Initialize the formatter either with the specified format string, or a default as described above. Allow for specialized date formatting with the optional `datefmt` argument. If `datefmt` is omitted, you get an ISO8601-like (or RFC 3339-like) format.

Use a style parameter of `'%'`, `'{'` or `'$'` to specify that you want to use one of %-formatting, `str.format()` (`{}`) formatting or `string.Template` formatting in your format string.

Changed in version 3.2: Added the `style` parameter.

**format** (*record*)

Format the specified record as text.

The record's attribute dictionary is used as the operand to a string formatting operation which yields the returned string. Before formatting the dictionary, a couple of preparatory steps are carried out. The message attribute of the record is computed using `LogRecord.getMessage()`. If the formatting string uses the time (as determined by a call to `usesTime()`, `formatTime()` is called to format the event time. If there is exception information, it is formatted using `formatException()` and appended to the message.

**class** `riscv_config.utils.SortingHelpFormatter` (*prog, indent\_increment=2, max\_help\_position=24, width=None*)

`riscv_config.utils.setup_logging` (*log\_level*)

Setup logging

Verbosity decided on user input

**Parameters** `log_level` (*str*) – User defined log level

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