

ALDCC simulator

1.0.0

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Chapter 1

Directory Hierarchy

1.1 Directories

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Chapter 2

Namespace Index

2.1 Namespace List

Here is a list of all namespaces with brief descriptions:

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constants	Global constants and configuration variables for the circuit solver	12

Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Context	A structure holding all runtime data and state for the circuit analysis	15
Element	Represents a single circuit component and its solved parameters	16
GivenValue	Holds information about the desired circuit output for the bisection method	19
cli::Input	Holds the parsed command-line input values	19

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File Index

4.1 File List

Here is a list of all files with brief descriptions:

include/bisect.hpp	21
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include/constants.hpp	24
include/context.hpp	25
include/element.hpp	25
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Chapter 5

Directory Documentation

5.1 include Directory Reference

Files

- file [bisect.hpp](#)
- file [cli.hpp](#)
- file [constants.hpp](#)
- file [context.hpp](#)
- file [element.hpp](#)
- file [file_io.hpp](#)
- file [solver.hpp](#)
- file [util.hpp](#)

5.2 src Directory Reference

Files

- file [bisect.cpp](#)
- file [cli.cpp](#)
- file [file_io.cpp](#)
- file [main.cpp](#)
- file [solver.cpp](#)
- file [util.cpp](#)

Chapter 6

Namespace Documentation

6.1 cli Namespace Reference

Contains functions and structures for command-line argument parsing.

Classes

- struct [Input](#)
Holds the parsed command-line input values.

Enumerations

- enum class [Switch](#) { [none](#) = 0 , [in](#) = 'i' , [out](#) = 'o' , [prec](#) = 'p' }
Defines the valid command-line switches for the program.

Functions

- [Input parse](#) (int argc, char *argv[])
Parses the command line arguments to extract input file, output file, and precision.

6.1.1 Detailed Description

Contains functions and structures for command-line argument parsing.

6.1.2 Enumeration Type Documentation

6.1.2.1 Switch

```
enum class cli::Switch [strong]
```

Defines the valid command-line switches for the program.

Enumerator

none	
in	
out	
prec	

6.1.3 Function Documentation

6.1.3.1 parse()

```
Input cli::parse (
    int argc,
    char * argv[ ])
```

Parses the command line arguments to extract input file, output file, and precision.

It checks for the '-i', '-o', and '-p' switches and reads the subsequent argument. It also prints usage instructions if no arguments are provided. Throws a std::runtime_error if a switch is expected but not found, or if the required input/output filenames are missing.

Parameters

argc	The number of command-line arguments.
argv	The array of command-line argument strings.

Returns

Input A struct containing the parsed input filename, output filename, and precision.

6.2 constants Namespace Reference

Global constants and configuration variables for the circuit solver.

Functions

- double prec_factor ()

Variables

- `uint32_t PRECISION = 4`
- `constexpr double ZERO_THRESHOLD = 1e-12`
- `constexpr double EPSILON = 2e-10`
- `constexpr uint32_t BISECTION_PREC = 50`

6.2.1 Detailed Description

Global constants and configuration variables for the circuit solver.

6.2.2 Function Documentation

6.2.2.1 prec_factor()

```
double constants::prec_factor () [inline]
```

6.2.3 Variable Documentation

6.2.3.1 BISECTION_PREC

```
uint32_t constants::BISECTION_PREC = 50 [constexpr]
```

6.2.3.2 EPSILON

```
double constants::EPSILON = 2e-10 [constexpr]
```

6.2.3.3 PRECISION

```
uint32_t constants::PRECISION = 4 [inline]
```

6.2.3.4 ZERO_THRESHOLD

```
double constants::ZERO_THRESHOLD = 1e-12 [constexpr]
```


Chapter 7

Class Documentation

7.1 Context Struct Reference

A structure holding all runtime data and state for the circuit analysis.

```
#include <context.hpp>
```

Public Attributes

- `uint8_t max_node = 0`
- `uint8_t number_of_unknowns = 0`
- `std::vector< Element > elements`
- `Element * variable_elem = nullptr`
- `GivenValue given_value`
- `double output_value = 0`
- `std::unordered_map< uint16_t, uint8_t > v_source_currents_map`
- `std::vector< std::vector< double > > equations`

7.1.1 Detailed Description

A structure holding all runtime data and state for the circuit analysis.

This includes the circuit elements, the maximum node index, the MNA system's equations, and state variables for the bisection algorithm.

7.1.2 Member Data Documentation

7.1.2.1 elements

```
std::vector<Element> Context::elements
```

7.1.2.2 equations

```
std::vector<std::vector<double> > Context::equations
```

7.1.2.3 `given_value`

```
GivenValue Context::given_value
```

7.1.2.4 `max_node`

```
uint8_t Context::max_node = 0
```

7.1.2.5 `number_of_unknowns`

```
uint8_t Context::number_of_unknowns = 0
```

7.1.2.6 `output_value`

```
double Context::output_value = 0
```

7.1.2.7 `v_source_currents_map`

```
std::unordered_map<uint16_t, uint8_t> Context::v_source_currents_map
```

7.1.2.8 `variable_elem`

```
Element* Context::variable_elem = nullptr
```

The documentation for this struct was generated from the following file:

- [include/context.hpp](#)

7.2 Element Struct Reference

Represents a single circuit component and its solved parameters.

```
#include <element.hpp>
```

Public Member Functions

- bool `is_directed_outwards` (const uint8_t node) const
Checks if the element's defined direction points away from a given node.
- int8_t `sign_of_current` (const uint8_t node) const
Gets the sign of the element's current with respect to a given node in KCL.
- uint8_t `other_node` (const uint8_t node) const
Finds the node at the other end of the element.

Public Attributes

- `ElementType type`
- `std::array< uint8_t, 2 > nodes`
- `double value`
- `double voltage`
- `double current`
- `double power`

7.2.1 Detailed Description

Represents a single circuit component and its solved parameters.

7.2.2 Member Function Documentation

7.2.2.1 `is_directed_outwards()`

```
bool Element::is_directed_outwards (
    const uint8_t node) const [inline]
```

Checks if the element's defined direction points away from a given node.

For sources, this indicates the current is flowing from `nodes[0]` to `nodes[1]`.

Parameters

<code>node</code>	The node to check against.
-------------------	----------------------------

Returns

`bool` True if the element's `nodes[0]` is the given node.

7.2.2.2 `other_node()`

```
uint8_t Element::other_node (
    const uint8_t node) const [inline]
```

Finds the node at the other end of the element.

Parameters

<code>node</code>	The known node.
-------------------	-----------------

Returns

`uint8_t` The index of the connecting node.

7.2.2.3 sign_of_current()

```
int8_t Element::sign_of_current (
    const uint8_t node) const [inline]
```

Gets the sign of the element's current with respect to a given node in KCL.

Current is defined as positive when leaving the node (+1) and negative when entering the node (-1).

Parameters

<i>node</i>	The node of interest.
-------------	-----------------------

Returns

int8_t 1 if current is directed out of the node, -1 if directed into the node.

7.2.3 Member Data Documentation

7.2.3.1 current

```
double Element::current
```

7.2.3.2 nodes

```
std::array<uint8_t, 2> Element::nodes
```

7.2.3.3 power

```
double Element::power
```

7.2.3.4 type

```
ElementType Element::type
```

7.2.3.5 value

```
double Element::value
```

7.2.3.6 voltage

```
double Element::voltage
```

The documentation for this struct was generated from the following file:

- [include/element.hpp](#)

7.3 GivenValue Struct Reference

Holds information about the desired circuit output for the bisection method.

```
#include <element.hpp>
```

Public Attributes

- `Element * elem`
- `ValueType v_type`
- `double desired_value`

7.3.1 Detailed Description

Holds information about the desired circuit output for the bisection method.

7.3.2 Member Data Documentation

7.3.2.1 `desired_value`

```
double GivenValue::desired_value
```

7.3.2.2 `elem`

```
Element* GivenValue::elem
```

7.3.2.3 `v_type`

```
ValueType GivenValue::v_type
```

The documentation for this struct was generated from the following file:

- `include/element.hpp`

7.4 cli::Input Struct Reference

Holds the parsed command-line input values.

```
#include <cli.hpp>
```

Public Attributes

- `std::string ifname = ""`
- `std::string ofname = ""`
- `uint8_t prec = 4`

7.4.1 Detailed Description

Holds the parsed command-line input values.

7.4.2 Member Data Documentation

7.4.2.1 `ifname`

```
std::string cli::Input::ifname = ""
```

7.4.2.2 `ofname`

```
std::string cli::Input::ofname = ""
```

7.4.2.3 `prec`

```
uint8_t cli::Input::prec = 4
```

The documentation for this struct was generated from the following file:

- [include/cli.hpp](#)

Chapter 8

File Documentation

8.1 include/bisect.hpp File Reference

```
#include "context.hpp"
```

Functions

- void `update_bisection_output (Context &ctx)`
Updates the output value for the bisection algorithm.
- int8_t `find_derivative_sign (Context &ctx)`
Determines the sign of the derivative of the output value with respect to the variable element value.
- double `find_bound (Context &ctx, int8_t derivative_sign)`
Finds an initial search bound for the bisection method.
- void `bisect (Context &ctx)`
Implements the bisection method to find the variable element's value that yields the desired output value.

8.1.1 Function Documentation

8.1.1.1 bisect()

```
void bisect (
    Context & ctx)
```

Implements the bisection method to find the variable element's value that yields the desired output value.

It iteratively narrows the search interval (`range[0]` and `range[1]`) based on the sign of the difference between the current output and the desired output, taking into account the derivative sign. The iteration runs for '`constants::BISECTION_PREC`' steps.

Parameters

<code>ctx</code>	The <code>Context</code> object containing all circuit data.
------------------	--

8.1.1.2 find_bound()

```
double find_bound (
    Context & ctx,
    int8_t derivative_sign)
```

Finds an initial search bound for the bisection method.

The function iteratively doubles an initial value until the sign of the difference between the current output and the desired output flips, indicating the solution is within the bounded range.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
<i>derivative_sign</i>	The sign of the output value's derivative (1 or -1).

Returns

double The calculated upper bound for the variable element's value.

8.1.1.3 find_derivative_sign()

```
int8_t find_derivative_sign (
    Context & ctx)
```

Determines the sign of the derivative of the output value with respect to the variable element value.

It checks how the `ctx.output_value` changes when the `ctx.variable_elem->value` is perturbed by a small value ([constants::EPSILON](#)). This determines the monotonic relationship used in the bisection.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
------------	---

Returns

`int8_t` 1 if the derivative is positive, -1 if negative.

8.1.1.4 update_bisection_output()

```
void update_bisection_output (
    Context & ctx)
```

Updates the output value for the bisection algorithm.

Based on the `ValueType` specified in `ctx.given_value`, this sets `ctx.output_value` to the voltage, current, or power of the monitored element. This function is called after a full circuit run to check the result.

Parameters

ctx	The Context object containing all circuit data.
-----	---

8.2 bisect.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include "context.hpp"
00003
00013 void update_bisection_output(Context& ctx);
00014
00024 int8_t find_derivative_sign(Context& ctx);
00025
00037 double find_bound(Context& ctx, int8_t derivative_sign);
00038
00048 void bisect(Context& ctx);
```

8.3 include/cli.hpp File Reference

```
#include <cstdint>
#include <string>
```

Classes

- struct [cli::Input](#)

Holds the parsed command-line input values.

Namespaces

- namespace [cli](#)

Contains functions and structures for command-line argument parsing.

Enumerations

- enum class [cli::Switch](#) { [cli::none](#) = 0 , [cli::in](#) = 'i' , [cli::out](#) = 'o' , [cli::prec](#) = 'p' }

Defines the valid command-line switches for the program.

Functions

- [Input cli::parse](#) (int argc, char *argv[])

Parses the command line arguments to extract input file, output file, and precision.

8.4 cli.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include <cstdint>
00003 #include <string>
00008 namespace cli {
00009
0013     enum class Switch {
0014         none = 0,
0015         in = 'i',
0016         out = 'o',
0017         prec = 'p'
0018     };
0019
0023     struct Input {
0024         std::string ifname = "";
0025         std::string ofname = "";
0026         uint8_t prec = 4;
0027     };
0028
0041     Input parse(int argc, char* argv[]);
0042 }
```

8.5 include/constants.hpp File Reference

```
#include "util.hpp"
```

Namespaces

- namespace **constants**
Global constants and configuration variables for the circuit solver.

Functions

- double constants::prec_factor ()

Variables

- uint32_t constants::PRECISION = 4
- constexpr double constants::ZERO_THRESHOLD = 1e-12
- constexpr double constants::EPSILON = 2e-10
- constexpr uint32_t constants::BISECTION_PREC = 50

8.6 constants.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include "util.hpp"
00003
00008 namespace constants {
00009     inline uint32_t PRECISION = 4;
0010     inline double prec_factor() { return power(10, PRECISION); }
0011     constexpr double ZERO_THRESHOLD = 1e-12;
0012     constexpr double EPSILON = 2e-10;
0013     constexpr uint32_t BISECTION_PREC = 50;
0014 }
```

8.7 include/context.hpp File Reference

```
#include <cstdint>
#include <unordered_map>
#include <vector>
#include "element.hpp"
```

Classes

- struct [Context](#)

A structure holding all runtime data and state for the circuit analysis.

8.8 context.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include <cstdint>
00003 #include <unordered_map>
00004 #include <vector>
00005
00006 #include "element.hpp"
00007
00015 struct Context {
00016     uint8_t max_node = 0;
00017     uint8_t number_of_unknowns = 0;
00018     std::vector<Element> elements;
00019
00020     Element* variable_elem = nullptr;
00021     GivenValue given_value;
00022     double output_value = 0;
00023
00024     std::unordered_map<uint16_t, uint8_t> v_source_currents_map;
00025     std::vector<std::vector<double>> equations;
00026 };
```

8.9 include/element.hpp File Reference

```
#include <array>
#include <cstdint>
```

Classes

- struct [Element](#)

Represents a single circuit component and its solved parameters.

- struct [GivenValue](#)

Holds information about the desired circuit output for the bisection method.

Enumerations

- enum [ElementType](#) { `v_source` = 'E', `c_source` = 'J', `resistor` = 'R' }
- Enumeration of supported circuit element types.*
- enum class [ValueType](#) { `voltage` = 'U', `current` = 'I', `power` = 'P' }
- Enumeration of the measurable values that can be the target for the bisection algorithm.*

8.9.1 Enumeration Type Documentation

8.9.1.1 ElementType

```
enum ElementType
```

Enumeration of supported circuit element types.

The values are set to the single-character representation used in the input file.

Enumerator

v_source	
c_source	
resistor	

8.9.1.2 ValueType

```
enum class ValueType [strong]
```

Enumeration of the measurable values that can be the target for the bisection algorithm.

The values are set to the single-character representation used in the input file.

Enumerator

voltage	
current	
power	

8.10 element.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include <array>
00003 #include <cstdint>
00004
00010 enum ElementType {
00011     v_source = 'E',
00012     c_source = 'J',
00013     resistor = 'R'
00014 };
00015
00020 struct Element {
00021     ElementType type;
00022     std::array<uint8_t, 2> nodes;
00023     double value;
00024
00025     double voltage;
00026     double current;
00027     double power;
00028
00029     bool is_directed_outwards(const uint8_t node) const {
00030         return nodes[0] == node;
00031     }
00032
00033     int8_t sign_of_current(const uint8_t node) const {
00034         return static_cast<int8_t>(2 * is_directed_outwards(node) - 1); // 1 if current leaves, -1
when enters
```

```

00049     }
00050
00057     uint8_t other_node(const uint8_t node) const {
00058         return nodes[0] == node? nodes[1] : nodes[0];
00059     }
00060 };
00061
00067 enum class ValueType {
00068     voltage = 'U',
00069     current = 'I',
00070     power = 'P'
00071 };
00072
00077 struct GivenValue {
00078     Element* elem;
00079     ValueType v_type;
00080     double desired_value;
00081 };

```

8.11 include/file_io.hpp File Reference

```
#include <string>
#include "context.hpp"
```

Functions

- bool `read (Context &ctx, const std::string &filename)`
Reads circuit element data from an input file.
- void `write_element (std::ofstream &file, const Element &elem)`
Writes the solved parameters (voltage, current, power) for a single element to the output file.
- void `write (const Context &ctx, const std::vector< double > &potentials, const std::string &filename, bool do_bisection)`
Writes the final results of the circuit analysis to the output file.

8.11.1 Function Documentation

8.11.1.1 `read()`

```
bool read (
    Context & ctx,
    const std::string & filename)
```

Reads circuit element data from an input file.

Parses each line for element type, node 1, node 2, and element value. It also detects the presence of a variable element (missing value) and a desired output value for the bisection method. Updates the `ctx.max_node`. Throws a `std::runtime_error` on failure to read, too many variable elements, or mismatched solving procedure (variable element vs. given value).

Parameters

<code>ctx</code>	The <code>Context</code> object to store the parsed data.
<code>filename</code>	The name of the input file.

Returns

`bool` True if a variable element and desired output were found, indicating bisection is needed.

8.11.1.2 write()

```
void write (
    const Context & ctx,
    const std::vector< double > & potentials,
    const std::string & filename,
    bool do_bisection)
```

Writes the final results of the circuit analysis to the output file.

Includes the element table (U, I, P) and the node potential table (V). If bisection was performed, it also writes the final value of the variable element. Applies rounding to the specified precision.

Parameters

<i>ctx</i>	The Context object containing the elements and bisection data.
<i>potentials</i>	The vector of solved node potentials.
<i>filename</i>	The name of the output file.
<i>do_bisection</i>	Boolean flag indicating if bisection was performed.

8.11.1.3 write_element()

```
void write_element (
    std::ofstream & file,
    const Element & elem)
```

Writes the solved parameters (voltage, current, power) for a single element to the output file.

The output is formatted into columns with alignment and rounding applied.

Parameters

<i>file</i>	The output file stream.
<i>elem</i>	The Element object to write.

8.12 file_io.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include <string>
00003
00004 #include "context.hpp"
00005
00019 bool read(Context& ctx, const std::string& filename);
00020
00029 void write_element(std::ofstream& file, const Element& elem);
00030
00043 void write(const Context& ctx, const std::vector<double>& potentials, const std::string& filename,
    bool do_bisection);
```

8.13 include/solver.hpp File Reference

```
#include "context.hpp"
```

Functions

- `std::vector< double > run (Context &ctx, bool do_bisection)`
Runs the main circuit analysis procedure.
- `void find_equations (Context &ctx)`
Constructs the system of linear equations for the circuit using Modified Nodal Analysis (MNA).
- `void solve (Context &ctx)`
Solves the system of linear equations stored in the context using Gaussian elimination with partial pivoting.
- `std::pair< std::vector< double >, std::vector< double > > decode_and_normalize (Context &ctx)`
Decodes the results from the reduced row echelon form of the equations.
- `void finalize (Context &ctx, const std::vector< double > &potentials, const std::vector< double > ¤ts)`
Calculates and updates the voltage, current, and power for every circuit element.

8.13.1 Function Documentation

8.13.1.1 decode_and_normalize()

```
std::pair< std::vector< double >, std::vector< double > > decode_and_normalize (
    Context & ctx)
```

Decodes the results from the reduced row echelon form of the equations.

Extracts the solved node potentials and voltage source currents from the matrix. It also checks for and handles rows representing identity and throws an error if the circuit is contradictory or not fully determinate.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
------------------	---

Returns

`std::pair<std::vector<double>, std::vector<double>>` A pair of vectors: the first contains node potentials, the second contains voltage source currents.

8.13.1.2 finalize()

```
void finalize (
    Context & ctx,
    const std::vector< double > & potentials,
    const std::vector< double > & currents)
```

Calculates and updates the voltage, current, and power for every circuit element.

Uses the solved node potentials and voltage source currents to determine the final operating parameters for all resistors, current sources, and voltage sources.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
<i>potentials</i>	A vector of solved node potentials.
<i>currents</i>	A vector of solved voltage source currents.

8.13.1.3 find_equations()

```
void find_equations (
    Context & ctx)
```

Constructs the system of linear equations for the circuit using Modified Nodal Analysis (MNA).

This function creates equations based on:

1. Ground node (Node 1) potential is zero.
2. Voltage sources (introducing a new unknown for every voltage source current).
3. Kirchhoff's Current Law (KCL) for every non-ground node.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
------------	---

8.13.1.4 run()

```
std::vector< double > run (
    Context & ctx,
    bool do_bisection)
```

Runs the main circuit analysis procedure.

Finds all necessary nodal and source equations, solves the resulting system of linear equations and decodes the results into node potentials and source currents. If bisection is enabled, it updates the output value for the bisection algorithm.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
<i>do_bisection</i>	Boolean flag indicating whether to perform bisection updates.

Returns

`std::vector<double>` A vector of solved node potentials.

8.13.1.5 solve()

```
void solve (
    Context & ctx)
```

Solves the system of linear equations stored in the context using Gaussian elimination with partial pivoting.

The equations are represented as an augmented matrix stored in `ctx.equations`. After solving, the matrix is in reduced row echelon form. Throws a `std::runtime_error` if contradictory equations are found.

Parameters

<code>ctx</code>	The <code>Context</code> object containing all circuit data.
------------------	--

8.14 solver.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include "context.hpp"
00003
00016 std::vector<double> run(Context& ctx, bool do_bisection);
00017
00028 void find_equations(Context& ctx);
00029
00039 void solve(Context& ctx);
00040
00052 std::pair<std::vector<double>, std::vector<double>> decode_and_normalize(Context& ctx);
00053
00064 void finalize(Context& ctx, const std::vector<double>& potentials, const std::vector<double>& currents);
```

8.15 include/util.hpp File Reference

```
#include <cstdint>
#include <vector>
#include "element.hpp"
```

Functions

- `uint8_t get_number_of_unknowns (const std::vector< Element > &elements, uint8_t max_node)`

Calculates the total number of unknowns in the MNA system.
- `void init_vector (std::vector< double > &vector, uint8_t n)`

Initializes a vector of doubles with a specified number of zeros.
- `void insert_ground_node_equation (std::vector< std::vector< double > > &equations, uint8_t unknowns)`

Inserts the equation for the ground node (Node 1) into the system.
- `uint16_t node_key (uint8_t node_0, uint8_t node_1)`

Creates a unique 16-bit key for a node pair, independent of the order.
- `bool current_source_only_node (const std::vector< Element > &elements, uint8_t max_node)`

Checks if there is a node connected only to current sources.
- `bool parallel_voltage_sources (const std::vector< Element > &elements)`

Checks for voltage sources connected in parallel.
- `double avg (double a, double b)`

Calculates the average (arithmetic mean) of two double-precision numbers.
- `constexpr double power (double base, int exp)`

Calculates the base raised to the power of the exponent.
- `double round_to_prec (double value)`

Rounds a double-precision value to the specified number of significant digits.

8.15.1 Function Documentation

8.15.1.1 avg()

```
double avg (
    double a,
    double b)
```

Calculates the average (arithmetic mean) of two double-precision numbers.

Parameters

<i>a</i>	The first number.
<i>b</i>	The second number.

Returns

double The average of *a* and *b*.

8.15.1.2 current_source_only_node()

```
bool current_source_only_node (
    const std::vector< Element > & elements,
    uint8_t max_node)
```

Checks if there is a node connected only to current sources.

This condition makes the node's voltage indeterminate, as only KCL equations (which govern current) apply, not Ohm's law (which relates voltage and current).

Parameters

<i>elements</i>	A constant reference to the vector of circuit elements.
<i>max_node</i>	The highest node index.

Returns

bool True if such a node exists, false otherwise.

8.15.1.3 get_number_of_unknowns()

```
uint8_t get_number_of_unknowns (
    const std::vector< Element > & elements,
    uint8_t max_node)
```

Calculates the total number of unknowns in the MNA system.

The number of unknowns is equal to the maximum node index (for node potentials) plus the number of voltage sources (for voltage source currents).

Parameters

<i>elements</i>	A constant reference to the vector of circuit elements.
<i>max_node</i>	The highest node index in the circuit.

Returns

`uint8_t` The total number of unknowns.

8.15.1.4 init_vector()

```
void init_vector (
    std::vector< double > & vector,
    uint8_t n)
```

Initializes a vector of doubles with a specified number of zeros.

Parameters

<i>vector</i>	The vector to be initialized.
<i>n</i>	The number of zeros to append.

8.15.1.5 insert_ground_node_equation()

```
void insert_ground_node_equation (
    std::vector< std::vector< double > > & equations,
    uint8_t unknowns)
```

Inserts the equation for the ground node (Node 1) into the system.

Parameters

<i>equations</i>	The vector of equation rows (augmented matrix).
<i>unknowns</i>	The total number of unknowns in the system.

8.15.1.6 node_key()

```
uint16_t node_key (
    uint8_t node_0,
    uint8_t node_1)
```

Creates a unique 16-bit key for a node pair, independent of the order.

The key is constructed by shifting the greater node to the upper 8 bits and the smaller node to the lower 8 bits.

Parameters

<i>node_0</i>	The first node index.
<i>node_1</i>	The second node index.

Returns

uint16_t The unique node key.

8.15.1.7 parallel_voltage_sources()

```
bool parallel_voltage_sources (
    const std::vector< Element > & elements)
```

Checks for voltage sources connected in parallel.

Parallel voltage sources (connected to the same two nodes) lead to an indeterminate current in the branches, making the system unsolvable.

Parameters

<i>elements</i>	A constant reference to the vector of circuit elements.
-----------------	---

Returns

bool True if parallel voltage sources are found, false otherwise.

8.15.1.8 power()

```
double power (
    double base,
    int exp) [constexpr]
```

Calculates the base raised to the power of the exponent.

This is a `constexpr` implementation of the power function for use in compile-time calculations.

Parameters

<i>base</i>	The number to be raised to a power.
<i>exp</i>	The integer exponent.

Returns

double The result of base to the power of exp.

8.15.1.9 round_to_prec()

```
double round_to_prec (
    double value)
```

Rounds a double-precision value to the specified number of significant digits.

Uses `constants::prec_factor()` to scale the value for rounding. Special handling to ensure negative zero is not returned.

Parameters

<i>value</i>	The value to be rounded.
--------------	--------------------------

Returns

double The rounded value.

8.16 util.hpp

[Go to the documentation of this file.](#)

```
00001 #pragma once
00002 #include <cstdint>
00003 #include <vector>
00004
00005 #include "element.hpp"
00006
00017 uint8_t get_number_of_unknowns(const std::vector<Element>& elements, uint8_t max_node);
00018
00025 void init_vector(std::vector<double>& vector, uint8_t n);
00026
00033 void insert_ground_node_equation(std::vector<std::vector<double>>& equations, uint8_t unknowns);
00034
00045 uint16_t node_key(uint8_t node_0, uint8_t node_1);
00046
00057 bool current_source_only_node(const std::vector<Element>& elements, uint8_t max_node);
00058
00068 bool parallel_voltage_sources(const std::vector<Element>& elements);
00069
00077 double avg(double a, double b);
00078
00089 constexpr double power(double base, int exp) {
00090     double result = 1.0;
00091     while (exp-- > 0) result *= base;
00092     return result;
00093 }
00094
00104 double round_to_prec(double value);
```

8.17 src/bisect.cpp File Reference

```
#include "bisect.hpp"
#include "element.hpp"
#include "constants.hpp"
#include "solver.hpp"
#include "util.hpp"
```

Functions

- void [update_bisection_output \(Context &ctx\)](#)
Updates the output value for the bisection algorithm.
- int8_t [find_derivative_sign \(Context &ctx\)](#)
Determines the sign of the derivative of the output value with respect to the variable element value.
- double [find_bound \(Context &ctx, int8_t derivative_sign\)](#)
Finds an initial search bound for the bisection method.
- void [bisect \(Context &ctx\)](#)
Implements the bisection method to find the variable element's value that yields the desired output value.

8.17.1 Function Documentation

8.17.1.1 bisect()

```
void bisect (
    Context & ctx)
```

Implements the bisection method to find the variable element's value that yields the desired output value.

It iteratively narrows the search interval (`range[0]` and `range[1]`) based on the sign of the difference between the current output and the desired output, taking into account the derivative sign. The iteration runs for '[constants::BISECTION_PREC](#)' steps.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
------------------	---

8.17.1.2 find_bound()

```
double find_bound (
    Context & ctx,
    int8_t derivative_sign)
```

Finds an initial search bound for the bisection method.

The function iteratively doubles an initial value until the sign of the difference between the current output and the desired output flips, indicating the solution is within the bounded range.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
<code>derivative_sign</code>	The sign of the output value's derivative (1 or -1).

Returns

`double` The calculated upper bound for the variable element's value.

8.17.1.3 find_derivative_sign()

```
int8_t find_derivative_sign (
    Context & ctx)
```

Determines the sign of the derivative of the output value with respect to the variable element value.

It checks how the `ctx.output_value` changes when the `ctx.variable_elem->value` is perturbed by a small value ([constants::EPSILON](#)). This determines the monotonic relationship used in the bisection.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
------------------	---

Returns

`int8_t` 1 if the derivative is positive, -1 if negative.

8.17.1.4 update_bisection_output()

```
void update_bisection_output (
    Context & ctx)
```

Updates the output value for the bisection algorithm.

Based on the [ValueType](#) specified in `ctx.given_value`, this sets `ctx.output_value` to the voltage, current, or power of the monitored element. This function is called after a full circuit run to check the result.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
------------------	---

8.18 src/cli.cpp File Reference

```
#include "cli.hpp"
#include <cstdint>
#include <iostream>
#include <stdexcept>
#include <string>
```

Namespaces

- namespace `cli`
Contains functions and structures for command-line argument parsing.

Functions

- `Input cli::parse (int argc, char *argv[])`
Parses the command line arguments to extract input file, output file, and precision.

8.19 src/file_io.cpp File Reference

```
#include <fstream>
#include <iomanip>
#include <sstream>
#include <cmath>
#include "file_io.hpp"
#include "constants.hpp"
```

Functions

- `bool read (Context &ctx, const std::string &filename)`
Reads circuit element data from an input file.
- `void write_element (std::ofstream &file, const Element &elem)`
Writes the solved parameters (voltage, current, power) for a single element to the output file.
- `void write (const Context &ctx, const std::vector< double > &potentials, const std::string &filename, bool do_bisection)`
Writes the final results of the circuit analysis to the output file.

8.19.1 Function Documentation

8.19.1.1 `read()`

```
bool read (
    Context & ctx,
    const std::string & filename)
```

Reads circuit element data from an input file.

Parses each line for element type, node 1, node 2, and element value. It also detects the presence of a variable element (missing value) and a desired output value for the bisection method. Updates the `ctx.max_node`. Throws a `std::runtime_error` on failure to read, too many variable elements, or mismatched solving procedure (variable element vs. given value).

Parameters

<i>ctx</i>	The Context object to store the parsed data.
<i>filename</i>	The name of the input file.

Returns

`bool` True if a variable element and desired output were found, indicating bisection is needed.

8.19.1.2 write()

```
void write (
    const Context & ctx,
    const std::vector< double > & potentials,
    const std::string & filename,
    bool do_bisection)
```

Writes the final results of the circuit analysis to the output file.

Includes the element table (U, I, P) and the node potential table (V). If bisection was performed, it also writes the final value of the variable element. Applies rounding to the specified precision.

Parameters

<i>ctx</i>	The Context object containing the elements and bisection data.
<i>potentials</i>	The vector of solved node potentials.
<i>filename</i>	The name of the output file.
<i>do_bisection</i>	Boolean flag indicating if bisection was performed.

8.19.1.3 write_element()

```
void write_element (
    std::ofstream & file,
    const Element & elem)
```

Writes the solved parameters (voltage, current, power) for a single element to the output file.

The output is formatted into columns with alignment and rounding applied.

Parameters

<i>file</i>	The output file stream.
<i>elem</i>	The Element object to write.

8.20 src/main.cpp File Reference

```
#include "util.hpp"
#include "solver.hpp"
#include "file_io.hpp"
#include "bisect.hpp"
#include "context.hpp"
#include "cli.hpp"
#include "constants.hpp"
#include <fstream>
```

Functions

- int **main** (int argc, char *argv[])

8.20.1 Function Documentation

8.20.1.1 main()

```
int main (
    int argc,
    char * argv[])
```

8.21 src/solver.cpp File Reference

```
#include <array>
#include <cmath>
#include <cstdint>
#include <fstream>
#include <ranges>
#include <vector>
#include "util.hpp"
#include "solver.hpp"
#include "bisect.hpp"
#include "constants.hpp"
```

Functions

- std::vector< double > **run** (**Context** &ctx, bool do_bisection)

Runs the main circuit analysis procedure.
- void **find_equations** (**Context** &ctx)

Constructs the system of linear equations for the circuit using Modified Nodal Analysis (MNA).
- void **solve** (**Context** &ctx)

Solves the system of linear equations stored in the context using Gaussian elimination with partial pivoting.
- std::pair< std::vector< double >, std::vector< double > > **decode_and_normalize** (**Context** &ctx)

Decodes the results from the reduced row echelon form of the equations.
- void **finalize** (**Context** &ctx, const std::vector< double > &potentials, const std::vector< double > ¤ts)

Calculates and updates the voltage, current, and power for every circuit element.

8.21.1 Function Documentation

8.21.1.1 decode_and_normalize()

```
std::pair< std::vector< double >, std::vector< double > > decode_and_normalize (
    Context & ctx)
```

Decodes the results from the reduced row echelon form of the equations.

Extracts the solved node potentials and voltage source currents from the matrix. It also checks for and handles rows representing identity and throws an error if the circuit is contradictory or not fully determinate.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
------------	---

Returns

`std::pair<std::vector<double>, std::vector<double>>` A pair of vectors: the first contains node potentials, the second contains voltage source currents.

8.21.1.2 finalize()

```
void finalize (
    Context & ctx,
    const std::vector< double > & potentials,
    const std::vector< double > & currents)
```

Calculates and updates the voltage, current, and power for every circuit element.

Uses the solved node potentials and voltage source currents to determine the final operating parameters for all resistors, current sources, and voltage sources.

Parameters

<i>ctx</i>	The Context object containing all circuit data.
<i>potentials</i>	A vector of solved node potentials.
<i>currents</i>	A vector of solved voltage source currents.

8.21.1.3 find_equations()

```
void find_equations (
    Context & ctx)
```

Constructs the system of linear equations for the circuit using Modified Nodal Analysis (MNA).

This function creates equations based on:

1. Ground node (Node 1) potential is zero.

2. Voltage sources (introducing a new unknown for every voltage source current).
3. Kirchhoff's Current Law (KCL) for every non-ground node.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
------------------	---

8.21.1.4 run()

```
std::vector< double > run (
    Context & ctx,
    bool do_bisection)
```

Runs the main circuit analysis procedure.

Finds all necessary nodal and source equations, solves the resulting system of linear equations and decodes the results into node potentials and source currents. If bisection is enabled, it updates the output value for the bisection algorithm.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
<code>do_bisection</code>	Boolean flag indicating whether to perform bisection updates.

Returns

`std::vector<double>` A vector of solved node potentials.

8.21.1.5 solve()

```
void solve (
    Context & ctx)
```

Solves the system of linear equations stored in the context using Gaussian elimination with partial pivoting.

The equations are represented as an augmented matrix stored in `ctx.equations`. After solving, the matrix is in reduced row echelon form. Throws a `std::runtime_error` if contradictory equations are found.

Parameters

<code>ctx</code>	The Context object containing all circuit data.
------------------	---

8.22 src/util.cpp File Reference

```
#include "util.hpp"
#include <cmath>
#include "element.hpp"
#include <cstdint>
#include <vector>
#include "constants.hpp"
```

Functions

- `uint8_t get_number_of_unknowns (const std::vector< Element > &elements, const uint8_t max_node)`
Calculates the total number of unknowns in the MNA system.
- `void init_vector (std::vector< double > &vector, const uint8_t n)`
Initializes a vector of doubles with a specified number of zeros.
- `void insert_ground_node_equation (std::vector< std::vector< double > > &equations, const uint8_t unknowns)`
Inserts the equation for the ground node (Node 1) into the system.
- `uint16_t node_key (const uint8_t node_0, const uint8_t node_1)`
Creates a unique 16-bit key for a node pair, independent of the order.
- `bool current_source_only_node (const std::vector< Element > &elements, const uint8_t max_node)`
Checks if there is a node connected only to current sources.
- `bool parallel_voltage_sources (const std::vector< Element > &elements)`
Checks for voltage sources connected in parallel.
- `double avg (double a, double b)`
Calculates the average (arithmetic mean) of two double-precision numbers.
- `double round_to_prec (double value)`
Rounds a double-precision value to the specified number of significant digits.

8.22.1 Function Documentation

8.22.1.1 avg()

```
double avg (
    double a,
    double b)
```

Calculates the average (arithmetic mean) of two double-precision numbers.

Parameters

<code>a</code>	The first number.
<code>b</code>	The second number.

Returns

`double` The average of `a` and `b`.

8.22.1.2 current_source_only_node()

```
bool current_source_only_node (
    const std::vector< Element > & elements,
    uint8_t max_node)
```

Checks if there is a node connected only to current sources.

This condition makes the node's voltage indeterminate, as only KCL equations (which govern current) apply, not Ohm's law (which relates voltage and current).

Parameters

<i>elements</i>	A constant reference to the vector of circuit elements.
<i>max_node</i>	The highest node index.

Returns

bool True if such a node exists, false otherwise.

8.22.1.3 get_number_of_unknowns()

```
uint8_t get_number_of_unknowns (
    const std::vector< Element > & elements,
    uint8_t max_node)
```

Calculates the total number of unknowns in the MNA system.

The number of unknowns is equal to the maximum node index (for node potentials) plus the number of voltage sources (for voltage source currents).

Parameters

<i>elements</i>	A constant reference to the vector of circuit elements.
<i>max_node</i>	The highest node index in the circuit.

Returns

uint8_t The total number of unknowns.

8.22.1.4 init_vector()

```
void init_vector (
    std::vector< double > & vector,
    uint8_t n)
```

Initializes a vector of doubles with a specified number of zeros.

Parameters

<i>vector</i>	The vector to be initialized.
<i>n</i>	The number of zeros to append.

8.22.1.5 insert_ground_node_equation()

```
void insert_ground_node_equation (
    std::vector< std::vector< double > > & equations,
    uint8_t unknowns)
```

Inserts the equation for the ground node (Node 1) into the system.

Parameters

<i>equations</i>	The vector of equation rows (augmented matrix).
<i>unknowns</i>	The total number of unknowns in the system.

8.22.1.6 node_key()

```
uint16_t node_key (
    uint8_t node_0,
    uint8_t node_1)
```

Creates a unique 16-bit key for a node pair, independent of the order.

The key is constructed by shifting the greater node to the upper 8 bits and the smaller node to the lower 8 bits.

Parameters

<i>node_0</i>	The first node index.
<i>node_1</i>	The second node index.

Returns

`uint16_t` The unique node key.

8.22.1.7 parallel_voltage_sources()

```
bool parallel_voltage_sources (
    const std::vector< Element > & elements)
```

Checks for voltage sources connected in parallel.

Parallel voltage sources (connected to the same two nodes) lead to an indeterminate current in the branches, making the system unsolvable.

Parameters

<code>elements</code>	A constant reference to the vector of circuit elements.
-----------------------	---

Returns

`bool` True if parallel voltage sources are found, false otherwise.

8.22.1.8 round_to_prec()

```
double round_to_prec (
    double value)
```

Rounds a double-precision value to the specified number of significant digits.

Uses `constants::prec_factor()` to scale the value for rounding. Special handling to ensure negative zero is not returned.

Parameters

<code>value</code>	The value to be rounded.
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Returns

`double` The rounded value.

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