# Hardware Modeling [VU] (191.011)
# – WS25 –
## 9-Valued Logic and Resolution (IEEE 1164)

Florian Huemer & Sebastian Wiedemann & Dylan Baumann

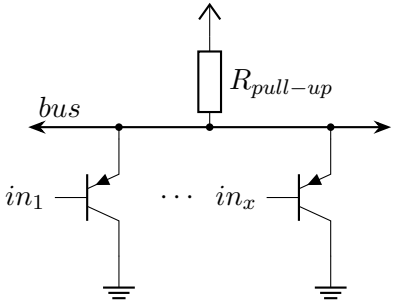
WS 2025/26

Modified: 2025-12-16, 18:01 (f8a58e9)

# Motivation | Wired-AND



- Example: Wired-AND circuit



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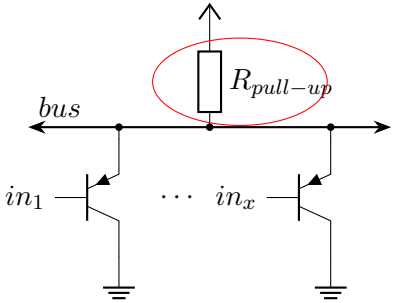

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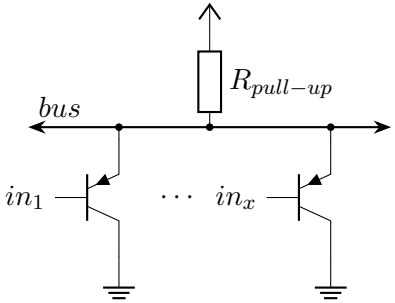

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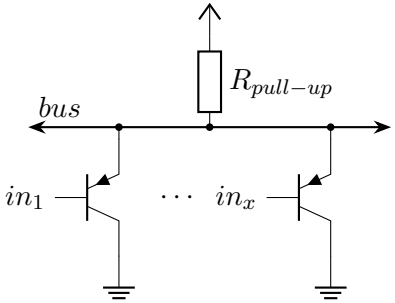

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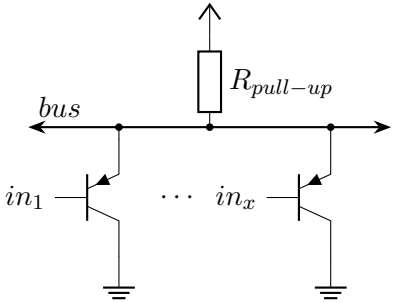

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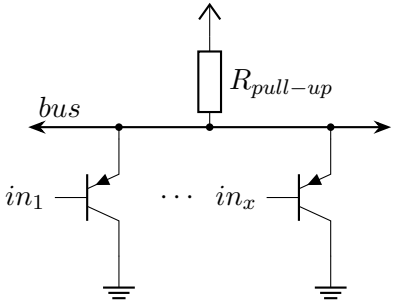

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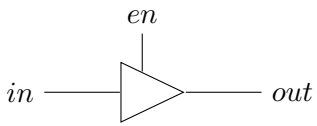

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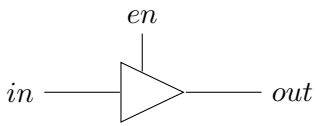

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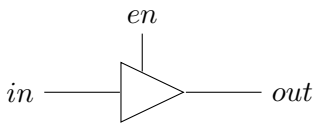

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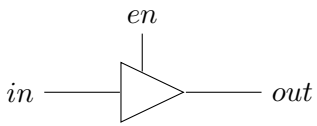

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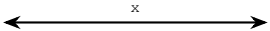


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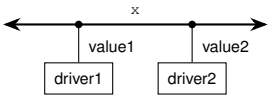

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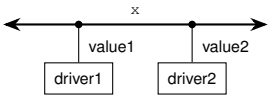

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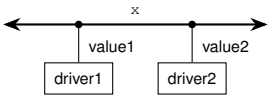


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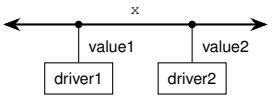


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```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4    ('U','U','U','U','U','U','U','U','U'),  -- U
5    ('U','X','X','X','X','X','X','X','X'),  -- X
6    ('U','X','0','X','0','0','0','0','X'),  -- 0
7    ('U','X','X','1','1','1','1','1','X'),  -- 1
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10   ('U','X','0','1','L','W','L','W','X'),  -- L
11   ('U','X','0','1','H','W','W','H','X'),  -- H
12   ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ------------------------------------------------
4    ('U','U','U','U','U','U','U','U','U'), -- U
5    ('U','X','X','X','X','X','X','X','X'), -- X
6    ('U','X','0','X','0','0','0','0','X'), -- 0
7    ('U','X','X','1','1','1','1','1','X'), -- 1
8    ('U','X','0','1','Z','W','L','H','X'), -- Z
9    ('U','X','0','1','W','W','W','W','X'), -- W
10   ('U','X','0','1','L','W','L','W','X'), -- L
11   ('U','X','0','1','H','W','W','H','X'), -- H
12   ('U','X','X','X','X','X','X','X','X')  -- -
13 );
```

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4    ('U','U','U','U','U','U','U','U','U'),  -- U
5    ('U','X','X','X','X','X','X','X','X'),  -- X
6    ('U','X','0','X','0','0','0','0','X'),  -- 0
7    ('U','X','X','1','1','1','1','1','X'),  -- 1
8    ('U','X','0','1','Z','W','L','H','X'),  -- Z
9    ('U','X','0','1','W','W','W','W','X'),  -- W
10   ('U','X','0','1','L','W','L','W','X'),  -- L
11   ('U','X','0','1','H','W','W','H','X'),  -- H
12   ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4    ('U','U','U','U','U','U','U','U','U'),  -- U
5    ('U','X','X','X','X','X','X','X','X'),  -- X
6    ('U','X','0','X','0','0','0','0','X'),  -- 0
7    ('U','X','X','1','1','1','1','1','X'),  -- 1
8    ('U','X','0','1','Z','W','L','H','X'),  -- Z
9    ('U','X','0','1','W','W','W','W','X'),  -- W
10   ('U','X','0','1','L','W','L','W','X'),  -- L
11   ('U','X','0','1','H','W','W','H','X'),  -- H
12   ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4    ('U','U','U','U','U','U','U','U','U'),  -- U
5    ('U','X','X','X','X','X','X','X','X'),  -- X
6    ('U','X','0','X','0','0','0','0','X'),  -- 0
7    ('U','X','X','1','1','1','1','1','X'),  -- 1
8    ('U','X','0','1','Z','W','L','H','X'),  -- Z
9    ('U','X','0','1','W','W','W','W','X'),  -- W
10   ('U','X','0','1','L','W','L','W','X'),  -- L
11   ('U','X','0','1','H','W','W','H','X'),  -- H
12   ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

# The std_ulogic Resolution Function (cont'd)

- The `RES_TABLE` defines how two values are resolved into one
  Example: pull-up (`'H'`), active (`'0'`) and inactive (`'Z'`) driver

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4   ('U','U','U','U','U','U','U','U','U'),  -- U
5   ('U','X','X','X','X','X','X','X','X'),  -- X
6   ('U','X','0','X','0','0','0','0','X'),  -- 0
7   ('U','X','X','1','1','1','1','1','X'),  -- 1
8   ('U','X','0','1','Z','W','L','H','X'),  -- Z
9   ('U','X','0','1','W','W','W','W','X'),  -- W
10  ('U','X','0','1','L','W','L','W','X'),  -- L
11  ('U','X','0','1','H','W','W','H','X'),  -- H
12  ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

`resolve("H0Z"):`

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one
  Example: pull-up (`'H'`), active (`'0'`) and inactive (`'Z'`) driver

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ---------------------------------------------
4   ('U','U','U','U','U','U','U','U','U'),  -- U
5   ('U','X','X','X','X','X','X','X','X'),  -- X
6   ('U','X','0','X','0','0','0','0','X'),  -- 0
7   ('U','X','X','1','1','1','1','1','X'),  -- 1
8   ('U','X','0','1','Z','W','L','H','X'),  -- Z
9   ('U','X','0','1','W','W','W','W','X'),  -- W
10  ('U','X','0','1','L','W','L','W','X'),  -- L
11  ('U','X','0','1','H','W','W','H','X'),  -- H
12  ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

```
resolve("H0Z"):
 1  RES_TABLE('Z', 'H') = 'H'
```

# The std_ulogic Resolution Function (cont'd)

- The `RES_TABLE` defines how two values are resolved into one
  Example: pull-up (`'H'`), active (`'0'`) and inactive (`'Z'`) driver

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ------------------------------------------------
4   ('U','U','U','U','U','U','U','U','U'),  -- U
5   ('U','X','X','X','X','X','X','X','X'),  -- X
6   ('U','X','0','X','0','0','0','0','X'),  -- 0
7   ('U','X','X','1','1','1','1','1','X'),  -- 1
8   ('U','X','0','1','Z','W','L','H','X'),  -- Z
9   ('U','X','0','1','W','W','W','W','X'),  -- W
10  ('U','X','0','1','L','W','L','W','X'),  -- L
11  ('U','X','0','1','H','W','W','H','X'),  -- H
12  ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

```
resolve("H0Z"):
  1  RES_TABLE('Z', 'H') = 'H'
  2  RES_TABLE('H', '0') = '0'
```

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one
  Example: pull-up (`'H'`), active (`'0'`) and inactive (`'Z'`) driver

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ---------------------------------------------
4   ('U','U','U','U','U','U','U','U','U'),  -- U
5   ('U','X','X','X','X','X','X','X','X'),  -- X
6   ('U','X','0','X','0','0','0','0','X'),  -- 0
7   ('U','X','X','1','1','1','1','1','X'),  -- 1
8   ('U','X','0','1','Z','W','L','H','X'),  -- Z
9   ('U','X','0','1','W','W','W','W','X'),  -- W
10  ('U','X','0','1','L','W','L','W','X'),  -- L
11  ('U','X','0','1','H','W','W','H','X'),  -- H
12  ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

```
resolve("H0Z"):
1  RES_TABLE('Z', 'H') = 'H'
2  RES_TABLE('H', '0') = '0'
3  RES_TABLE('0', 'Z') = '0'
```

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one
  Example: pull-up (`'H'`), active (`'0'`) and inactive (`'Z'`) driver

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4   ('U','U','U','U','U','U','U','U','U'),  -- U
5   ('U','X','X','X','X','X','X','X','X'),  -- X
6   ('U','X','0','X','0','0','0','0','X'),  -- 0
7   ('U','X','X','1','1','1','1','1','X'),  -- 1
8   ('U','X','0','1','Z','W','L','H','X'),  -- Z
9   ('U','X','0','1','W','W','W','W','X'),  -- W
10  ('U','X','0','1','L','W','L','W','X'),  -- L
11  ('U','X','0','1','H','W','W','H','X'),  -- H
12  ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

`resolve("H0Z"):`

1. `RES_TABLE('Z', 'H') = 'H'`
2. `RES_TABLE('H', '0') = '0'`
3. `RES_TABLE('0', 'Z') = '0'`

$\Rightarrow$ `resolve("H0Z") = '0'`

# The std_ulogic Resolution Function (cont'd)



- The `RES_TABLE` defines how two values are resolved into one
  Example: pull-up (`'H'`), active (`'0'`) and inactive (`'Z'`) driver

```
1  constant RES_TABLE: stdlogic_table := (
2  -- U    X    0    1    Z    W    L    H    -
3  ----------------------------------------------
4   ('U','U','U','U','U','U','U','U','U'),  -- U
5   ('U','X','X','X','X','X','X','X','X'),  -- X
6   ('U','X','0','X','0','0','0','0','X'),  -- 0
7   ('U','X','X','1','1','1','1','1','X'),  -- 1
8   ('U','X','0','1','Z','W','L','H','X'),  -- Z
9   ('U','X','0','1','W','W','W','W','X'),  -- W
10  ('U','X','0','1','L','W','L','W','X'),  -- L
11  ('U','X','0','1','H','W','W','H','X'),  -- H
12  ('U','X','X','X','X','X','X','X','X')   -- -
13 );
```

`resolve("H0Z"):`

1. `RES_TABLE('Z', 'H') = 'H'`
2. `RES_TABLE('H', '0') = '0'`
3. `RES_TABLE('0', 'Z') = '0'`

$\Rightarrow$ `resolve("H0Z") = '0'`

# Lecture Complete!