
Pump example

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1. System specification decomposition level 1

This chapter describes the system of interest at the first decomposition level. That is, it describes 2 components which play a role within the environment in which the system of interest must operate and the (functional) interactions between those components. In Figure 1.1 the associated design-structure-matrix (DSM) is shown. The DSM shows the dependencies between the elements that are relevant to this decomposition level.

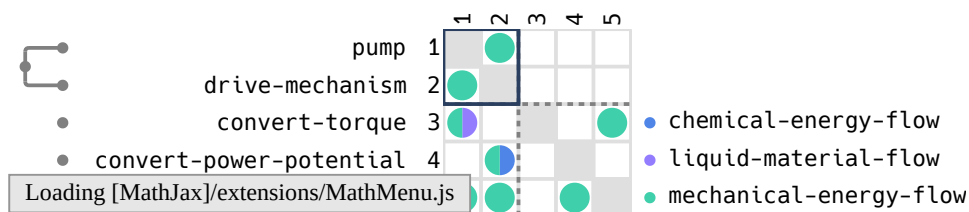


Figure 1.1.: component – function spec dependency matrix of decomposition level 1.

1.1. Drive-mechanism

This section describes **drive-mechanism**.

Properties:

The following properties are specified for drive-mechanism:

- drive-length

1.1.1. Goal function requirements

provide-torque

Drive-mechanism must provide torque to pump.

Comments

Dummy comment.

1.1.2. Transformation function requirements

drive-mechanism → convert-power-potential

Drive-mechanism must convert power-potential into torque.

Subordinate function specifications

drive-mechanism → power-source → convert-potential
drive-mechanism → motor → convert-power
drive-mechanism → bs-provide-power

1.1.3. Quantitative design constraints

drive-length-target

Drive-length must be equal to pump-length .

1.1.4. Qualitative design requirements

IP68

Drive-mechanism must be IP68 compliant.

cost

Drive-mechanism must be affordable.

reliability

Provide-torque must be very reliable.

1.1.5. External models

drive-mechanism → power-source → efficiency-model

model definition name

battery-efficiency-model

related variables

drive-mechanism → power-source → efficiency-model

drive-mechanism → power-potential

drive-mechanism → power

1.1.6. Sub-components

Drive-mechanism is composed of the following sub-components:

- kill-switch
- motor
- power-button
- power-source

1.2. Pump

This section describes **pump**.

Comments

Can be sourced by manufacturer XYZ. Part number CFG.PMP.0.1

Properties:

The following properties are specified for pump:

- pump-length

1.2.1. Transformation function requirements

pump → convert-torque

Pump must convert torque into water-flow.

1.2.2. Quantitative design requirements

min-water-flow

Water-flow must be at least 1.0 [L/s].

max-water-flow

Water-flow must be at most 3.0 [L/s].

1.2.3. Quantitative design constraints

drive-length-target

Drive-length must be equal to pump-length .

1.2.4. Qualitative design requirements

reliability

Provide-torque must be very reliable.

stability

Water-flow must be very stable.

2. System specification decomposition level 2

This chapters describes the system of interest at decomposition level 2 and introduces 4 additional components. In Figure 2.1 the associated design-structure-matrix (DSM) is shown. The DSM shows the dependencies between the elements that are relevant to this decomposition level.

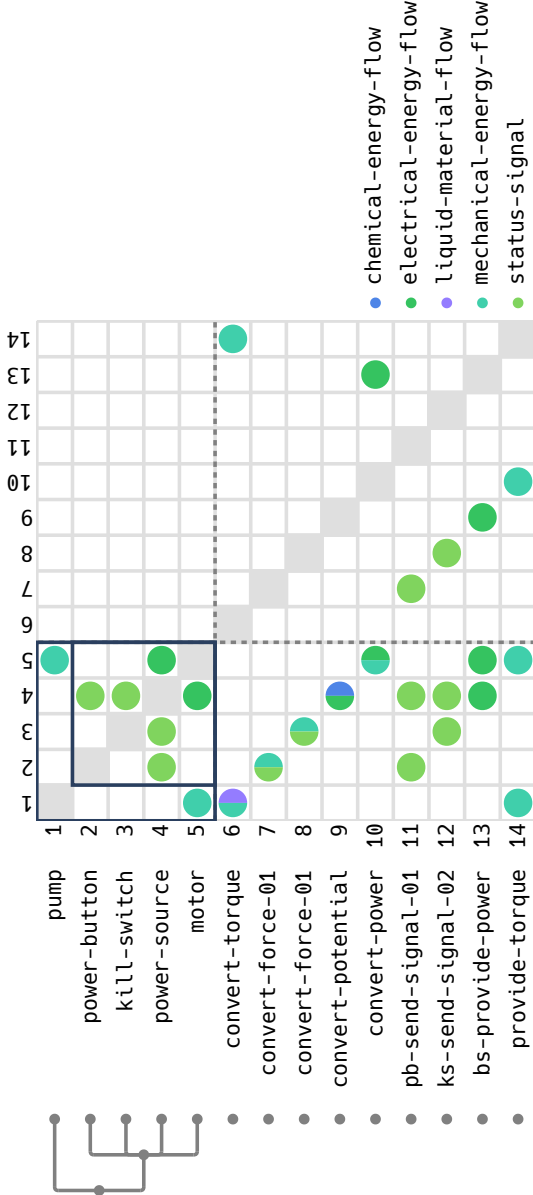


Figure 2.1.: component – function spec dependency matrix of decomposition level 2.

2.1. Power-button

This section describes **power-button**. This component is a sub-component of drive-mechanism.

Properties:

The following properties are specified for power-button:

- power-button-state

2.1.1. Goal function requirements

drive-mechanism → pb-send-signal-01

Power-button must send power-button-state to power-source.

2.1.2. Transformation function requirements

drive-mechanism → power-button → convert-force-01

Power-button must convert actuation-force into power-button-state.

2.1.3. Behavior requirements

drive-mechanism → power-button → button-state-behavior

Case *Pressed*:

when:

- button-position is smaller than 0

then:

- power-button-state must be equal to “Pressed” Case *NotPressed*:

when:

- button-position is at least 0

then:

- power-button-state must be equal to “NotPressed”
-

2.2. Kill-switch

This section describes **kill-switch**. This component is a sub-component of drive-mechanism.

Properties:

The following properties are specified for kill-switch:

- kill-switch-state

2.2.1. Goal function requirements

drive-mechanism → ks-send-signal-02

Kill-switch must send kill-switch-state to power-source.

2.2.2. Transformation function requirements

drive-mechanism → kill-switch → convert-force-01

Kill-switch must convert actuation-force into kill-switch-state.

2.2.3. Behavior requirements

drive-mechanism → kill-switch → button-state-behavior

Case *Pressed*:

when:

- button-position is smaller than 0

then:

- kill-switch-state must be equal to “Pressed” Case *NotPressed*:

when:

- button-position is at least 0

then:

- kill-switch-state must be equal to “NotPressed”
-

2.3. Power-source

This section describes **power-source**. This component is a sub-component of drive-mechanism.

2.3.1. Goal function requirements

drive-mechanism → bs-provide-power

Power-source must provide power to motor.

2.3.2. Transformation function constraints

drive-mechanism → power-source → convert-potential

Power-source does convert power-potential into power.

2.3.3. Behavior requirements

drive-mechanism → power-source → toggle-power

Case *on*:

when:

- power-button-state is equal to Pressed [-]

then:

- power must be at least 300 [W] Case *default*:

when no other case applies, then:

- power must be equal to 0 [W]
-

drive-mechanism → power-source → kill-power

Case *emergency*:

when:

- kill-switch-state is equal to Pressed [-]

then:

- power must be equal to 0 [W]
-

2.3.4. Quantitative design requirements

drive-mechanism → power-source → max-power

Power must be at most 400 [W].

2.3.5. External models

drive-mechanism → power-source → efficiency-model

model definition name

battery-efficiency-model

related variables

drive-mechanism → power-potential

drive-mechanism → power

drive-mechanism → power-source → heat-model

model definition name

battery-heat-generation-model

required variables

drive-mechanism → power

drive-mechanism → power-source → heat-generation-coefficient

returned variables

drive-mechanism → power-source → heat-flux

2.4. Motor

This section describes **motor**. This component is a sub-component of drive-mechanism.

2.4.1. Goal function requirements

provide-torque

Motor must provide torque to pump.

Comments

Dummy comment. This goal function requirement automatically migrated from drive-mechanism.

2.4.2. Transformation function requirements

drive-mechanism → motor → convert-power

Motor must convert power into torque, with subclauses:

- conversion must be at least 0.8

Subordinate function specifications

drive-mechanism → motor → rotor → ba-convert-flux-and-power

2.4.3. Quantitative design requirements

drive-mechanism → power-source → max-power

Power must be at most 400 [W].

2.4.4. Qualitative design requirements

reliability

Provide-torque must be very reliable.

2.4.5. External models

drive-mechanism → power-source → efficiency-model

model definition name

battery-efficiency-model

related variables

drive-mechanism → power-potential

drive-mechanism → power

drive-mechanism → power-source → heat-model

model definition name

battery-heat-generation-model

required variables

drive-mechanism → power

drive-mechanism → power-source → heat-generation-coefficient

returned variables

drive-mechanism → power-source → heat-flux

2.4.6. Sub-components

Motor is composed of the following sub-components:

- rotor
- stator

3. System specification decomposition level 3

This chapters describes the system of interest at decomposition level 3 and introduces 2 additional components. In Figure 3.1 the associated design-structure-matrix (DSM) is shown. The DSM shows the dependencies between the elements that are relevant to this decomposition level.

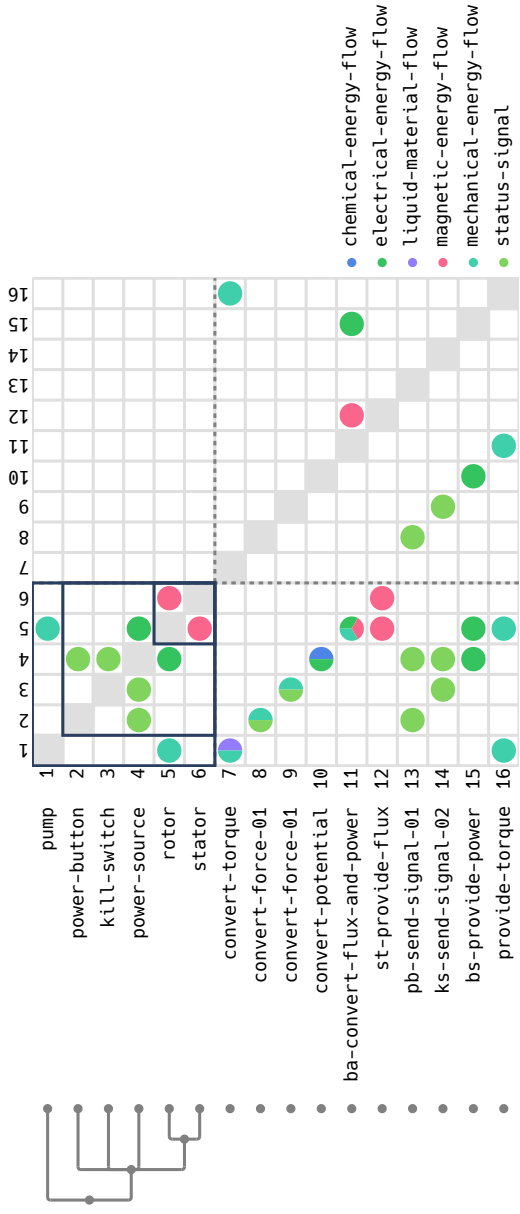


Figure 3.1.: component – function spec dependency matrix of decomposition level 3.

3.1. Rotor

This section describes **rotor**. This component is a sub-component of drive-mechanism → motor.

3.1.1. Goal function requirements

provide-torque

Rotor must provide torque to pump.

Comments

Dummy comment. This goal function requirement automatically migrated from drive-mechanism.

3.1.2. Transformation function requirements

drive-mechanism → motor → rotor → ba-convert-flux-and-power

Rotor must convert magnetic-flux and power into torque.

3.1.3. Quantitative design requirements

drive-mechanism → power-source → max-power

Power must be at most 400 [W].

3.1.4. Qualitative design requirements

reliability

Provide-torque must be very reliable.

3.1.5. External models

drive-mechanism → power-source → efficiency-model

model definition name

battery-efficiency-model

drive-mechanism → power-source → efficiency-model

related variables

drive-mechanism → power-potential

drive-mechanism → power

drive-mechanism → power-source → heat-model

model definition name

battery-heat-generation-model

required variables

drive-mechanism → power

drive-mechanism → power-source → heat-generation-coefficient

returned variables

drive-mechanism → power-source → heat-flux

3.2. Stator

This section describes **stator**. This component is a sub-component of drive-mechanism → motor.

3.2.1. Goal function requirements

drive-mechanism → motor → st-provide-flux

Stator must provide magnetic-flux to rotor.

Appendices

A. List of variables

A.1. Definitions

| Variable | Type | Domain | Units | Clarification |
|--|----------------------------|---|-------|---------------|
| drive-length | Spatial | $0.0 \leq x$ | | |
| drive-mechanism → kill-switch → actuation-force | Mechanical- energy-flow | | Nm | |
| drive-mechanism → kill-switch → button-position | Spatial | $0.0 \leq x$ | | |
| drive-mechanism → kill-switch-state | Status-signal | enumeration of Pressed and NotPressed | | |
| drive-mechanism → motor → conversion | Efficiency | $0.0 \leq x \leq 1.0$ | | |
| drive-mechanism → motor → magnetic-flux | Magnetic-energy- flow | | | |
| drive-mechanism → power | Electrical-energy- flow | | W | |
| drive-mechanism → power-button → actuation-force | Mechanical- energy-flow | | Nm | |
| drive-mechanism → power-button → button-position | Spatial | $0.0 \leq x$ | | |
| drive-mechanism → power-button- state | Status-signal | enumeration of Pressed and NotPressed | | |

| Variable | Type | Domain | Units | Clarification |
|--|----------------------------|--------------|-------|---------------|
| drive-mechanism → power-potential | Chemical-energy- flow | $0.0 \leq x$ | | |
| drive-mechanism → power-source → heat-flux | Thermal-energy- flow | | | |
| drive-mechanism → power-source → heat-generation- coefficient | Constant | | | |
| pump-length | Spatial | $0.0 \leq x$ | | |
| torque | Mechanical- energy-flow | | Nm | must be high. |
| water-flow | Liquid-material- flow | | L/s | |