

1. Objective

It is expected that in mass metrology, digital twins will be able to:

- Improve statistical controls.
- Correct mass measurements.
- Determine the optimal time for balance calibration.

Additionally, these tasks will be performed more quickly and securely, as the digital twin collects data directly from the instruments, eliminating the need for manual data transcription, which accelerates the process and reduces the likelihood of human error.

2. Introduction

In order to develop a digital twin, weight and balance models were first developed using Simulink. Table 1 summarizes the inputs, outputs, and subsystems for each model. The main diagram linking the weight and balance models is shown in Figure 1. Figure 2 illustrates the subsystems of both models, while Figure 3 provides a detailed description of a specific subsystem from each model. In Figures 2 and 3, the inputs and outputs of each subsystem are highlighted in green and yellow, respectively.

MODEL	INPUTS	OUTPUT	SUBSYSTEMS
Weight	• Air temperature • Air pressure • Air humidity	Weight's apparent mass	• Heat exchange • Volumetric expansion • Air buoyancy • Adsorption • Air current force (caused by thermal gradients) • Load cell • Indicator
Balance	• Air temperature • Weight's apparent mass	Mass reading	• Load cell • Indicator

Table 1: Inputs, outputs, and subsystems of the weight and balance models.

3. Main Diagram

The main Simulink block diagram shows the connection between the Weight and Balance models, along with their inputs and outputs.

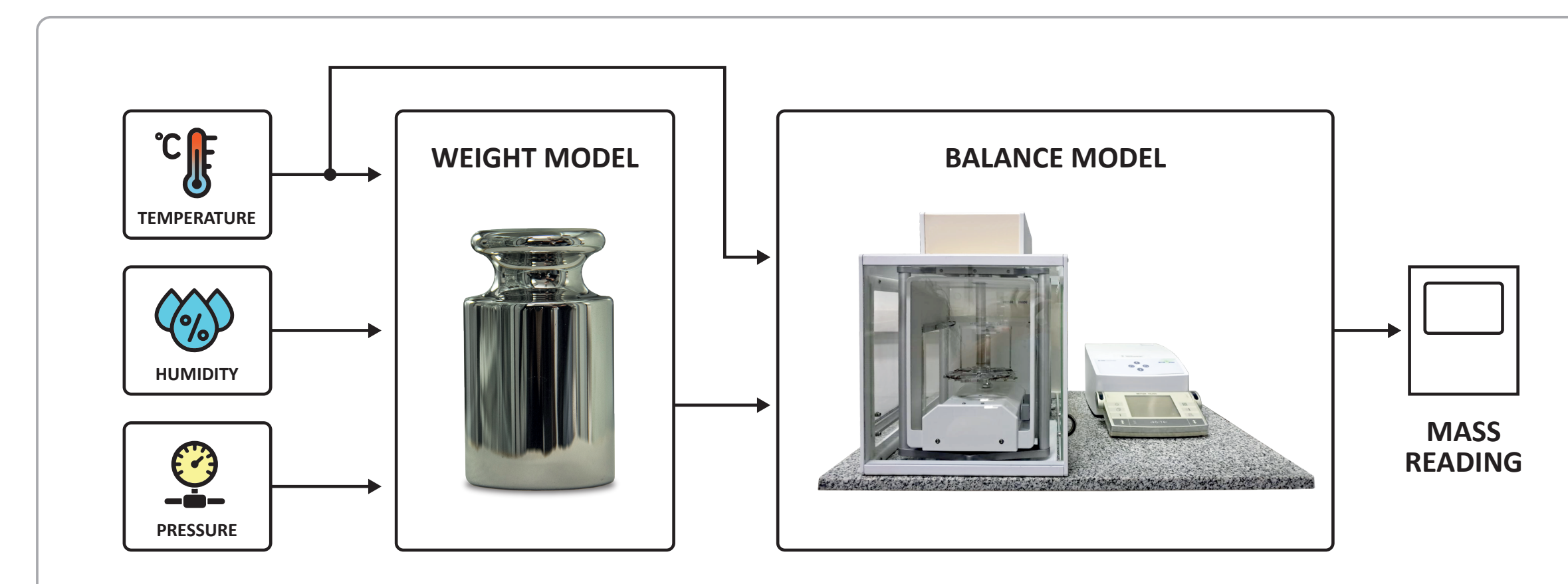


Figure 1: Main simulink block diagram.

4. Weight and balance models subsystems

The Weight Model has several subsystems that interact to determine the Weight's Apparent Mass.

The Balance Model has two subsystems: the Load Cell Subsystem and the Indicator Subsystem. The first determines the amount of current required to compensate for the force produced by the weight, while the second is responsible for converting this current into a mass reading, considering the coil temperature.

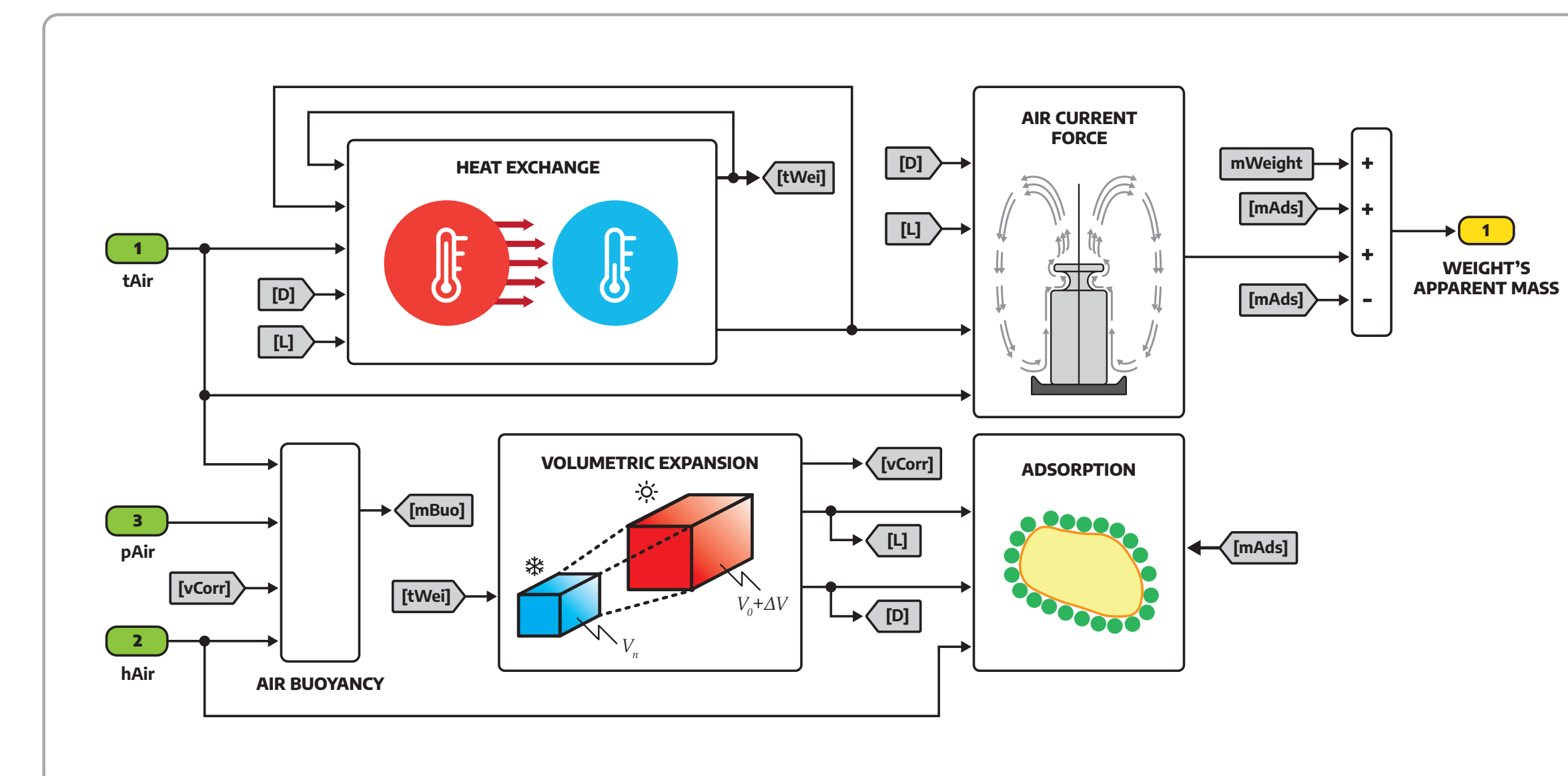


Figure 2a: Weight's subsystems.

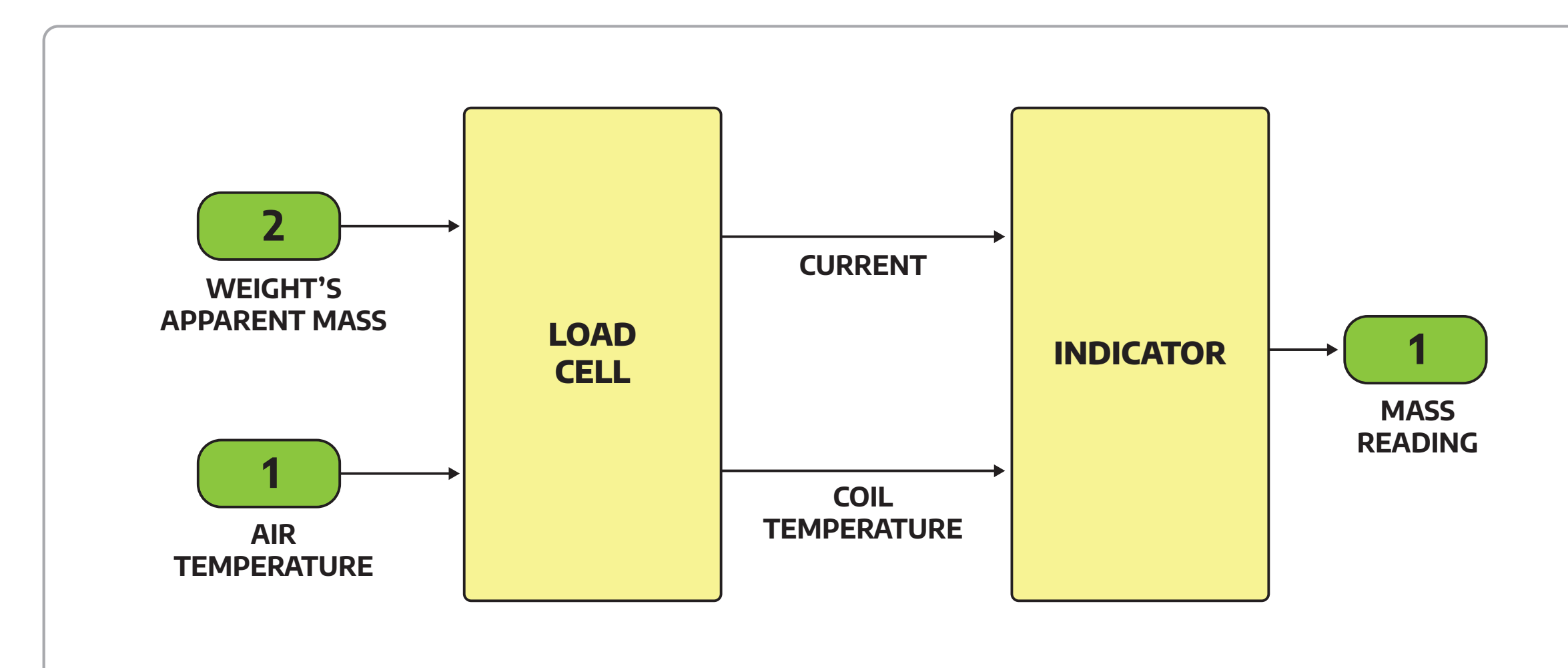


Figure 2b: Balance's subsystems.

The Heat Exchange Weight Subsystem uses an empirical fluid dynamics model that takes as inputs the diameter and length of the weight, the average and surface temperatures of the weight, and the temperature of the surrounding air. The outputs are the predicted temperatures (average and surface) of the weight at the subsequent time step. The Load Cell consists of a mechanical component based on a lever-pivot mechanism and an electrical component, which includes a coil, a permanent magnet, a position sensor, and a controller. The current passing through the coil, in combination with the permanent magnet, generates a Lorentz force that counteracts force produced by the weight, which in turn generates a moment around the pivot.

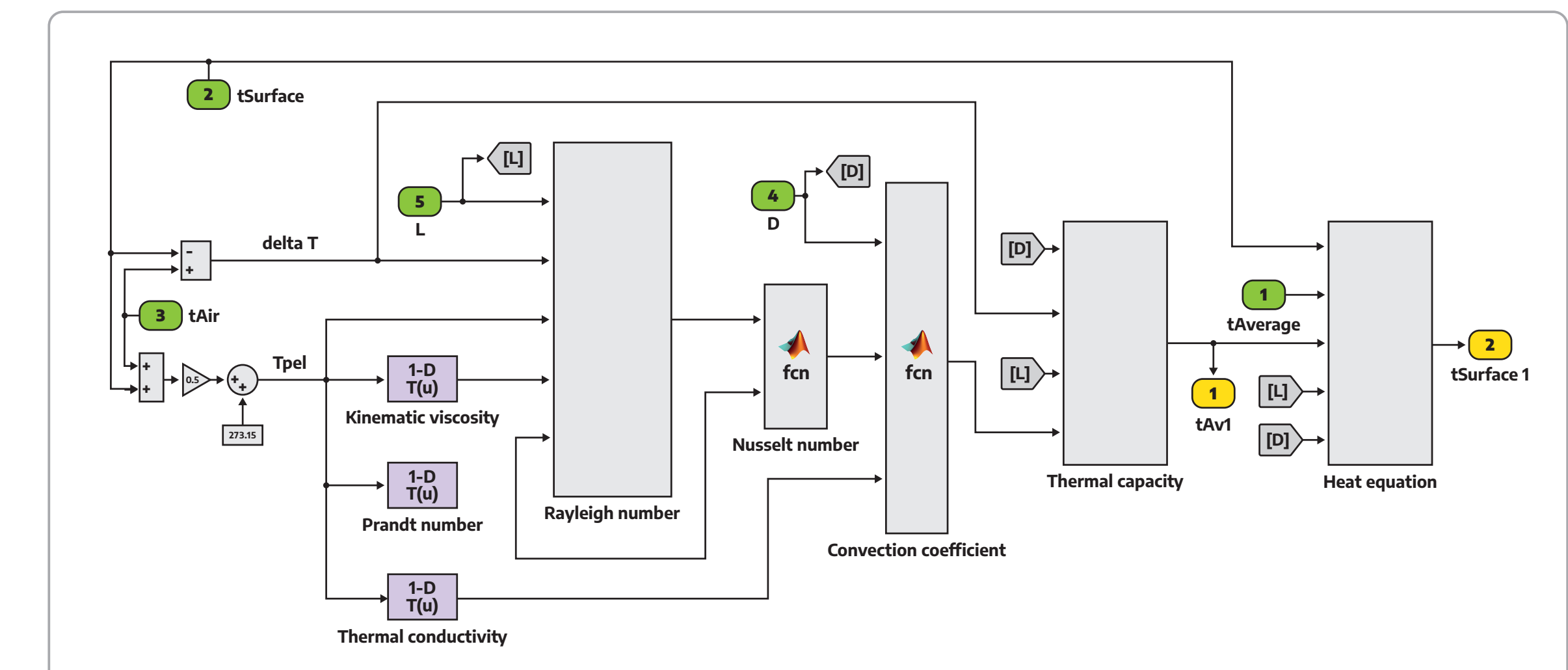


Figure 3a: Heat exchange weight subsystem.

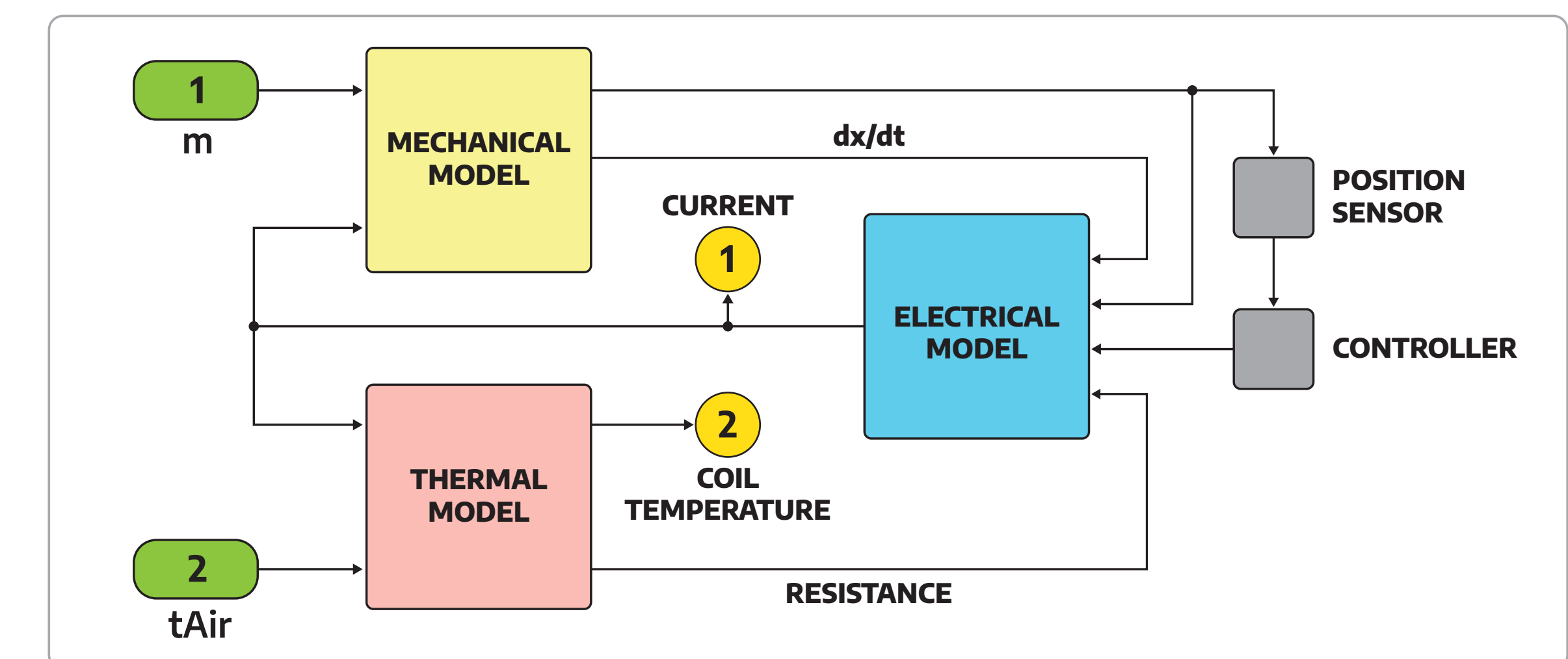


Figure 3b: Load cell balance subsystem.

5. Conclusion

The combination of a digital twin of a weight and a balance can be used to predict the standard deviation of a given measurement, forecast the drift in the balance reading, and identify the underlying causes to improve the accuracy of the measurements.

Creating a model of a balance allows for a deeper understanding of its operation, facilitating the identification of suitable sensors that could be integrated to monitor its performance and predict its deterioration over time, using data-driven models.

6. References

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