Model-2

Thermoelectric Regenerative Damper

Working of the Model

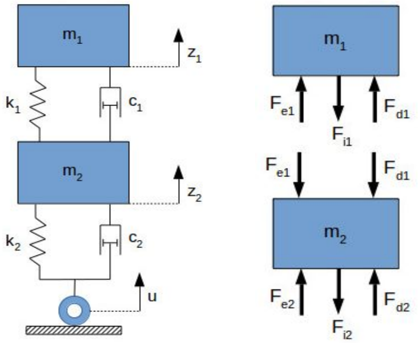
Car is driven through bumps → Damping procedure begins → Energy is dissipated in the form of thermal energy → This energy is absorbed by the seebeck module as well as the oil → Seebeck module converts the thermal energy into electrical energy → Electrical Power is Harvested for different purposes

Quarter Car Power Gen Model

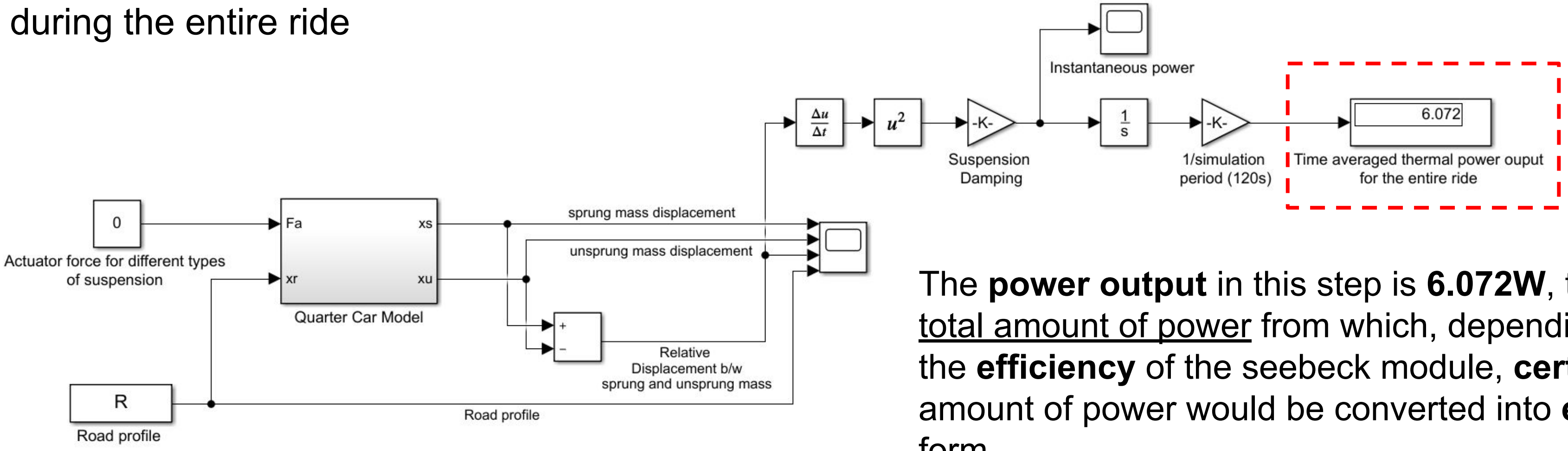
Governing **Equations**

- $$\frac{d^2z_1}{dt^2} = \frac{1}{m_1}\left(k_1(z_2 - z_1) + c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right)\right)$$
  $$\frac{d^2z_2}{dt^2} = \frac{1}{m_2}\left(k_2(u - z_2) + c_2\left(\frac{du}{dt} - \frac{dz_2}{dt}\right) - k_1(z_2 - z_1) - c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right)\right)$$

- $$P = \frac{1}{T}\int_0^T F_c(t)\bullet d[Z_s(t) - Z_u(t)]$$
  $$= \frac{1}{T}\int_0^T c_p(\dot{Z}_s(t) - \dot{Z}_u(t))^2\, dt$$

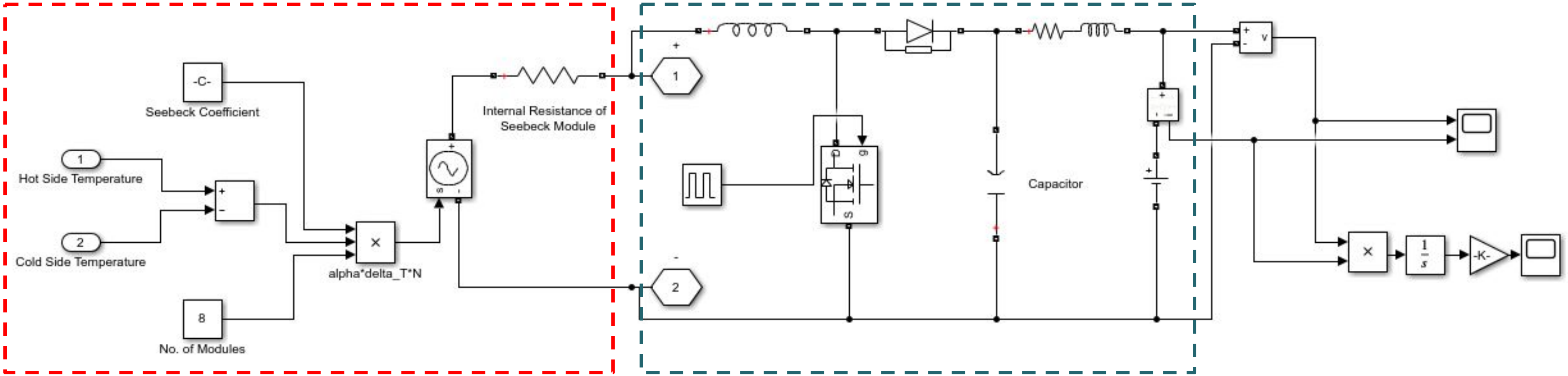


Simulink model to determine the **Thermal Power Output** during the entire ride



The **power output** in this step is **6.072W**, this is the <u>total amount of power</u> from which, depending upon the **efficiency** of the seebeck module, **certain** amount of power would be converted into **electrical** form.

Heat Energy to Electrical Energy Conversion



Model of Thermoelectric Generator (Seebeck Module)

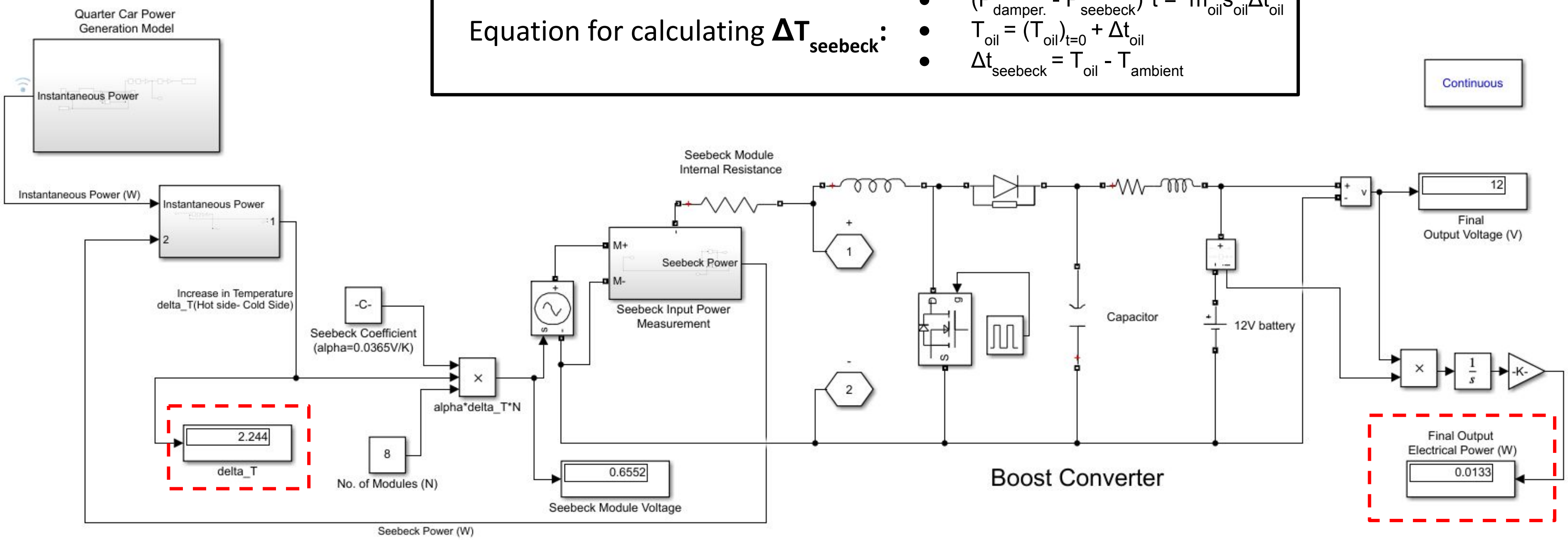
Boost Converter for storing energy in 12V battery

- Heat generated due to damper **increase damper oil temperature** which in turn creates a temperature difference between the hot and cold side of seebeck module, this temperature difference is responsible for generating voltage across seebeck module which is given by: $\mathbf{V_{TEG}= N*\alpha_{seebeck}*\Delta T}$
- Voltage of **8-seebeck modules in series** is then boosted to **12V** using a **boost converter** for charging **12V** battery for storing generated electrical energy.

Complete Regenerative Damper Model

Equation for calculating $\Delta T_{seebeck}$:

- $(P_{damper.} - P_{seebeck})*t = m_{oil}s_{oil}\Delta t_{oil}$
- $T_{oil} = (T_{oil})_{t=0} + \Delta t_{oil}$
- $\Delta t_{seebeck} = T_{oil} - T_{ambient}$



- After running the entire simulation we find that the final power harnessed from the shock absorber is around **13 mW** and output voltage of **12V** was generated.

Physical Model

Physical Construction

A number of seebeck modules are arranged around piston wall of a generic shock absorber.

Thermal paste is applied b/w the modules for better thermal contact and to avoid the formation of air bubbles.

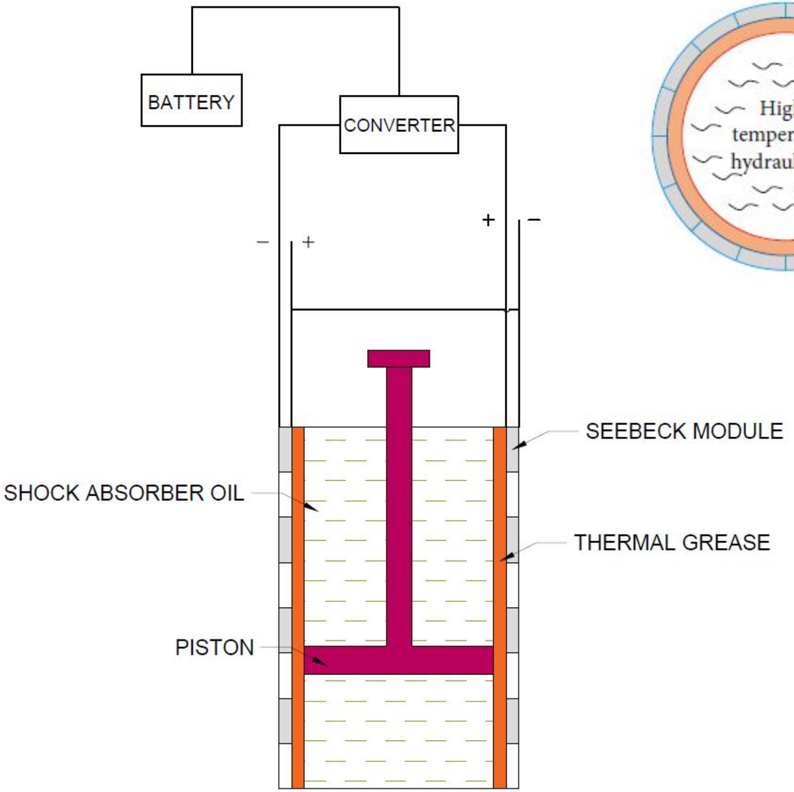
Dimensions

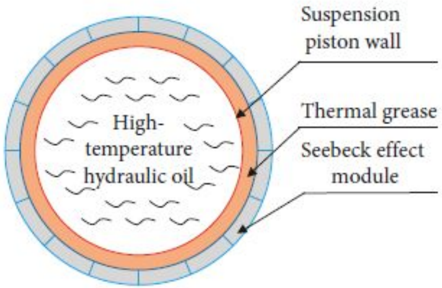
Damper
- Piston tube diameter :- 10cm
- Piston tube length :- 20cm
- Piston tube thickness :- 0.5 cm
- Net weight :- 2.63kg

TEG module
- No. of Modules (assumed) :- 8
- Seebeck module size :- 4cm x 4cm
- Weight of one module :- 40g
- Thickness :- 0.5cm

Converter
- Weight :- 100-200g

Total Weight of the System :- 470 + 2630 = 3100g





Difficulties in our Model

The biggest issue in our model was that we didn't take into account the relatively low amount of thermal power that would be generated through viscous damping during the entire ride. For 15 runs the average thermal power dissipated was **6.1W**.

This power is **not enough** to increase the temperature of the oil by any significant amount and since the power produced by a seebeck module **depends on the temperature difference** (**2.24 °C** for the simulations shown) between the hot and cold side of the thermocouple the final power output is lessened even more.

On top of that since the efficiency of a TEG module is around **2-3%**, the final output power harnessed is almost negligible and thus it **could not be utilized** to produce any useful work

By taking into account the above reasons we have deemed our model to be a **<u>FAILURE</u>**.

Even though our model failed for the constraints given in the problem statement our model could still be utilized in a successful manner for **heavy duty vehicles** working in rough road conditions

The power harnessed for such a case was estimated to be in the range of **few kW's**. This power can reduce the total fuel consumption of the truck by around **4%**.

References & Bibliography

9.0

Model 2

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