Power determination

Discussion of TP1 and TP2 and various hybrid configurations

May 10, 2019

Outstanding issue: Novel powertrains

Summary of outstanding issues

- Known prior to validation program:
  1) Greater variation observed for TP2 than for TP1 (based on Japan testing)
  2) Proposed requirement to collect fuel flow rate for TP1 (to verify per R85)
  3) Method for assessing tire losses for TP2 (if measurement is at dyno rolls)
  4) Allowability/impact of gear shifting on maximum power
  5) Should PHEV test be in CD or CS mode, and how to determine
  6) Applicability to novel or complex powertrains (multi motor, Rex, 4WD)
- Added by results of validation program:
  7) TP1 and TP2 results differ significantly
     - Use of default K factors can contribute to the difference
     - Slippage may contribute to the difference (affecting TP2 result)
     - Engine not being at maximum power point per R85 may contribute (affecting TP1)
  8) For some vehicles, repeatability was questionable
  9) Slippage may affect identification of maximum power, due to gearshift effects

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Noted at EVE-30 Stockholm

Novel powertrains and the premise that TP1 = TP2

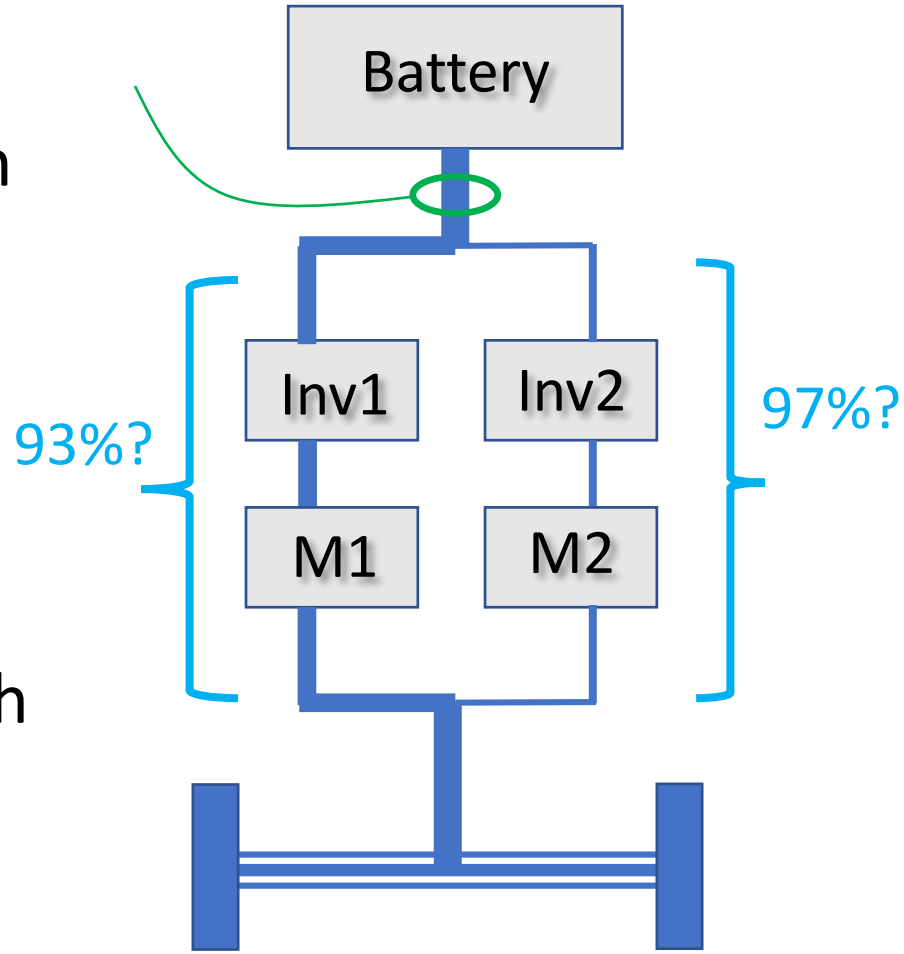
- At EVE30 in Stockholm it was suggested that the premise of TP1 = TP2 could be a basis for internal validation and verification of K factors.
- I therefore looked at all of the hybrid types with regard to:
  - Do TP1 and TP2 measure the same quantity?
  - Can we thus rely on the premise that TP1=TP2 when the measurements and the K factors are accurate?

Premise: TP1 = TP2

- Accuracy of either method should be the same, if the measurements and the K factors are equally accurate
- TP1 and TP2 are both valid for vehicles in which:
  - The current from the battery goes to a single inverter/motor combination (K1), and
  - The combined torque at each axle arrives via a single mechanical path (K2)
- TP1: what if the power from the battery splits into more than one path?
- TP2: what if the combined axle torque arrives by more than one path?
- In either case:
  - TP1 and TP2 may still be reasonable as standalone metrics of vehicle power.
  - But it may no longer be true that TP1 and TP2 are measuring the same thing.
  - Therefore, we cannot strongly rely on the premise that TP1 = TP2

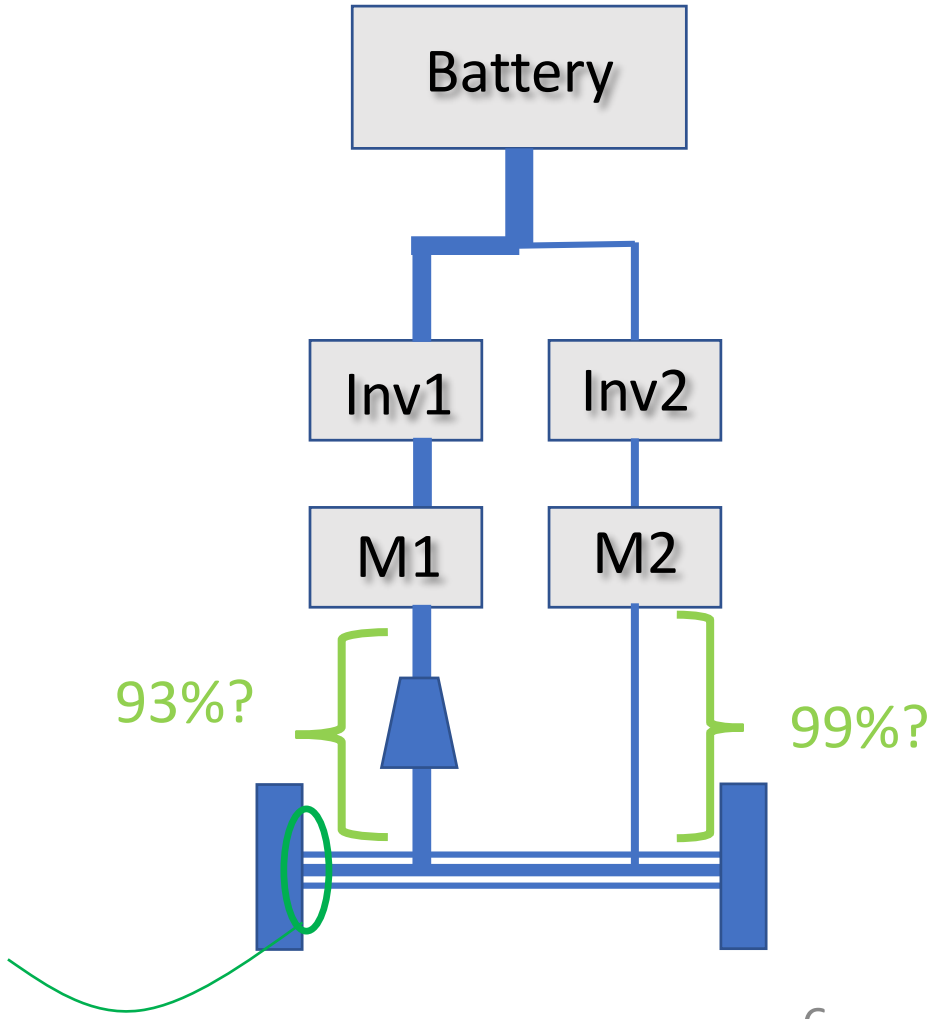
Weakness of TP1

- It relies on a single measure of power out of the battery. It cannot account for distribution of this power to different paths
- If battery power is distributed to more than one inverter/motor combination, and each has a different efficiency, a single K1 factor may not account for the losses
- It is more correct to measure power into each inverter, and apply a different K1 factor for each.

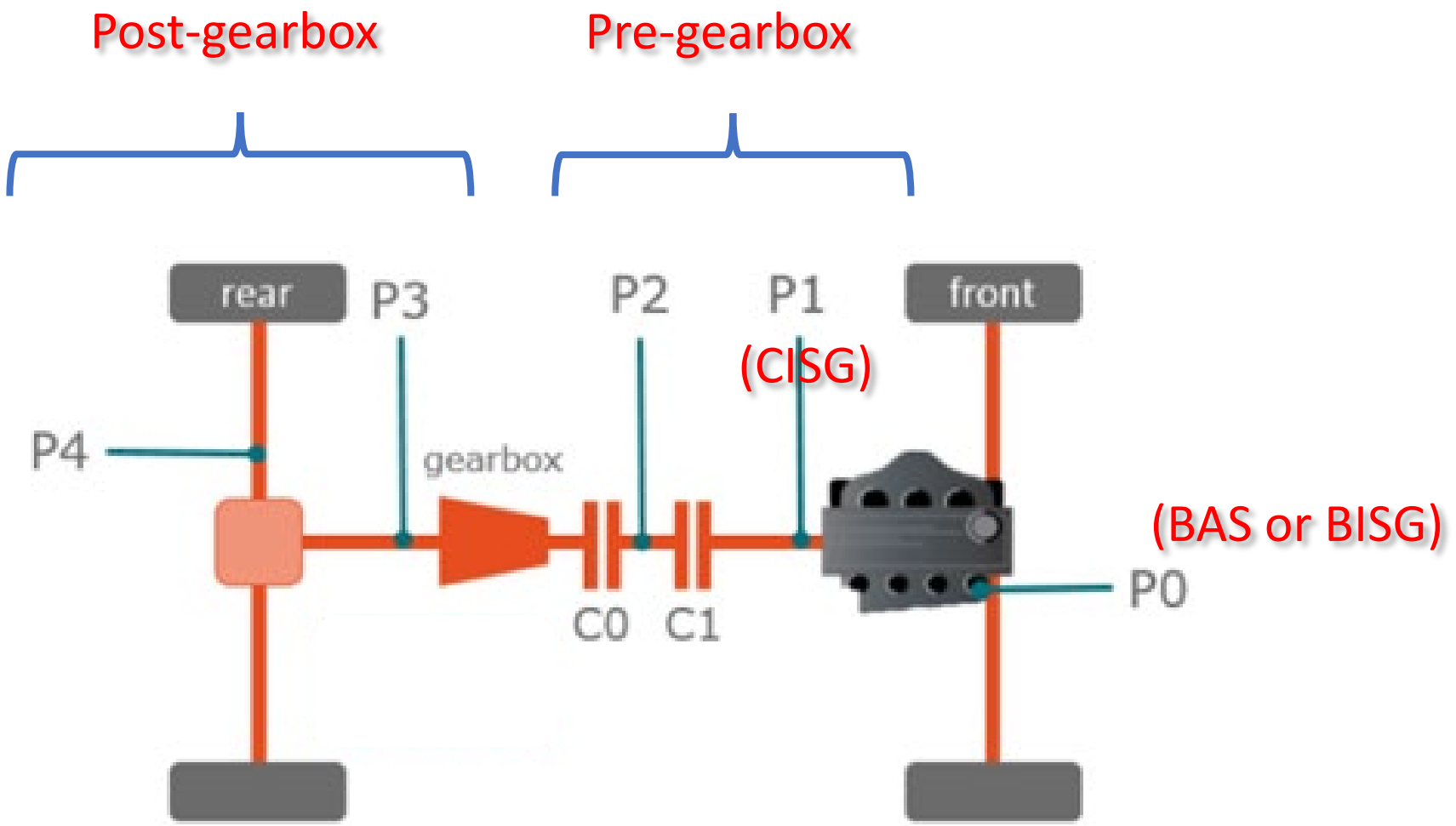


Weakness of TP2

- It relies on a measure of combined power at the axle. It cannot account for individual sources of power
- If the power to an axle is a combination of more than one source, but the power has arrived via different mechanical paths, a single K2 factor may not account for the losses.
- It is more correct to separate the combined axle power into its constituents, and apply a different K2 factor to each.

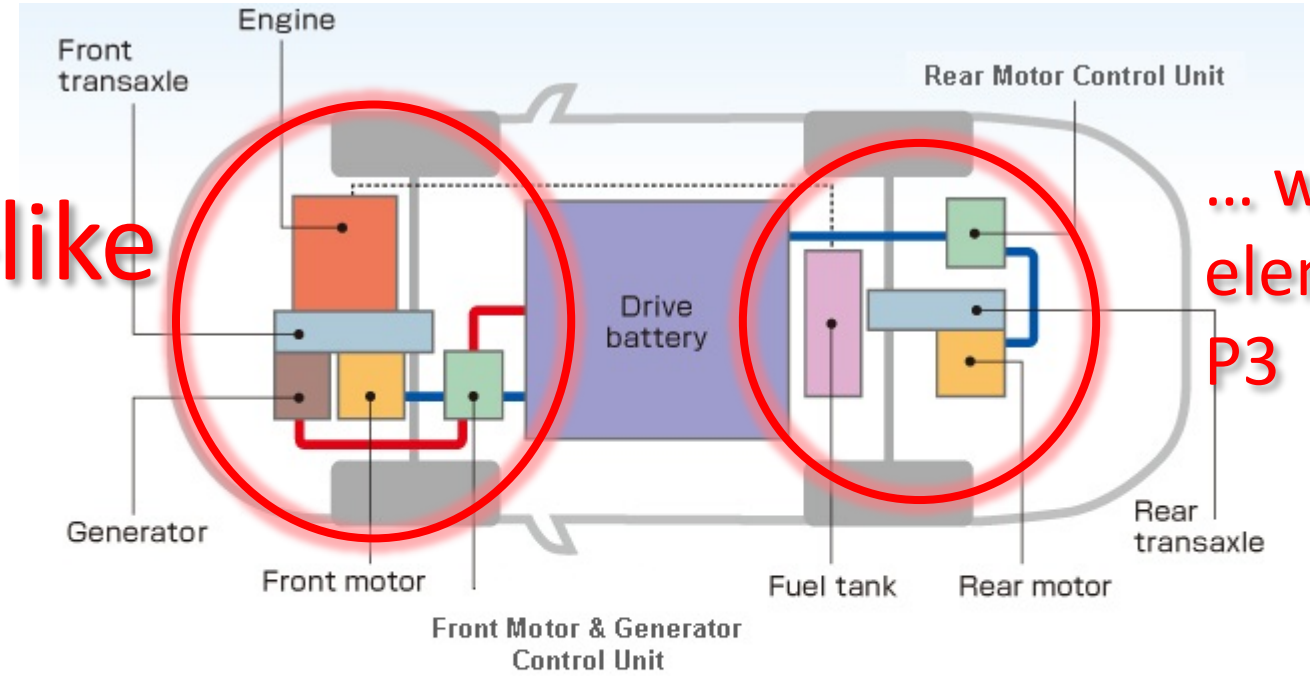


Motor position P0 – P4



Mitsubishi Outlander PHEV

PS-like



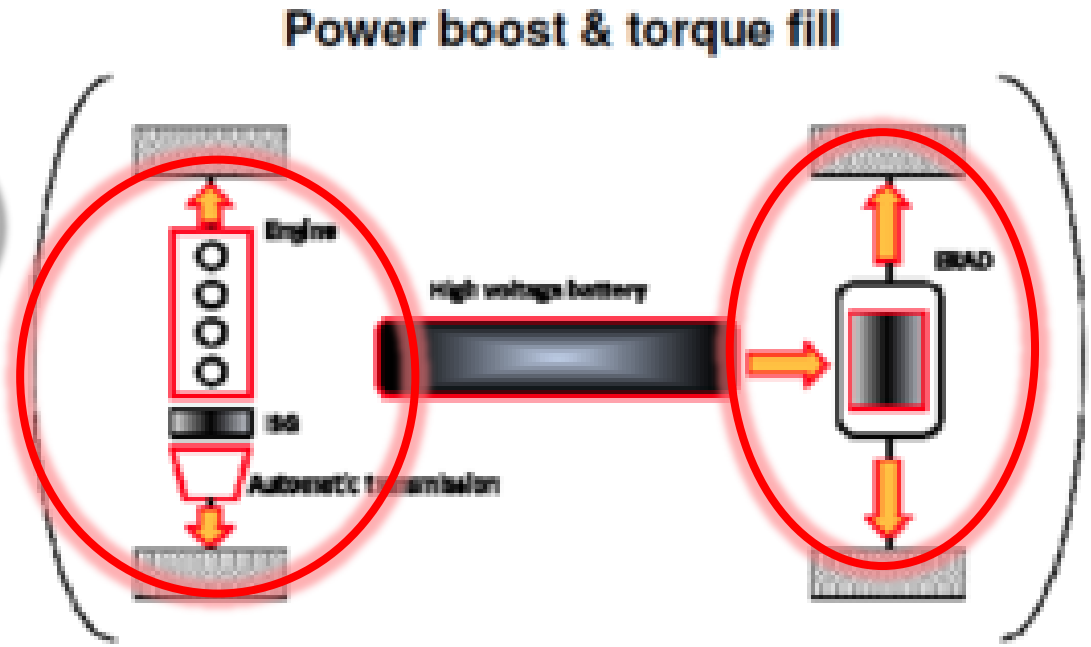
… with an element of P3

■ Specifications

Drive train	Twin motor 4WD	
Motor (Front/Rear)	Type	Permanent magnet synchronous
	Max Output	60kW each
Battery type	Li-ion	
Engine	2.0L 4-cylinder	

Volvo XC60 PHEV

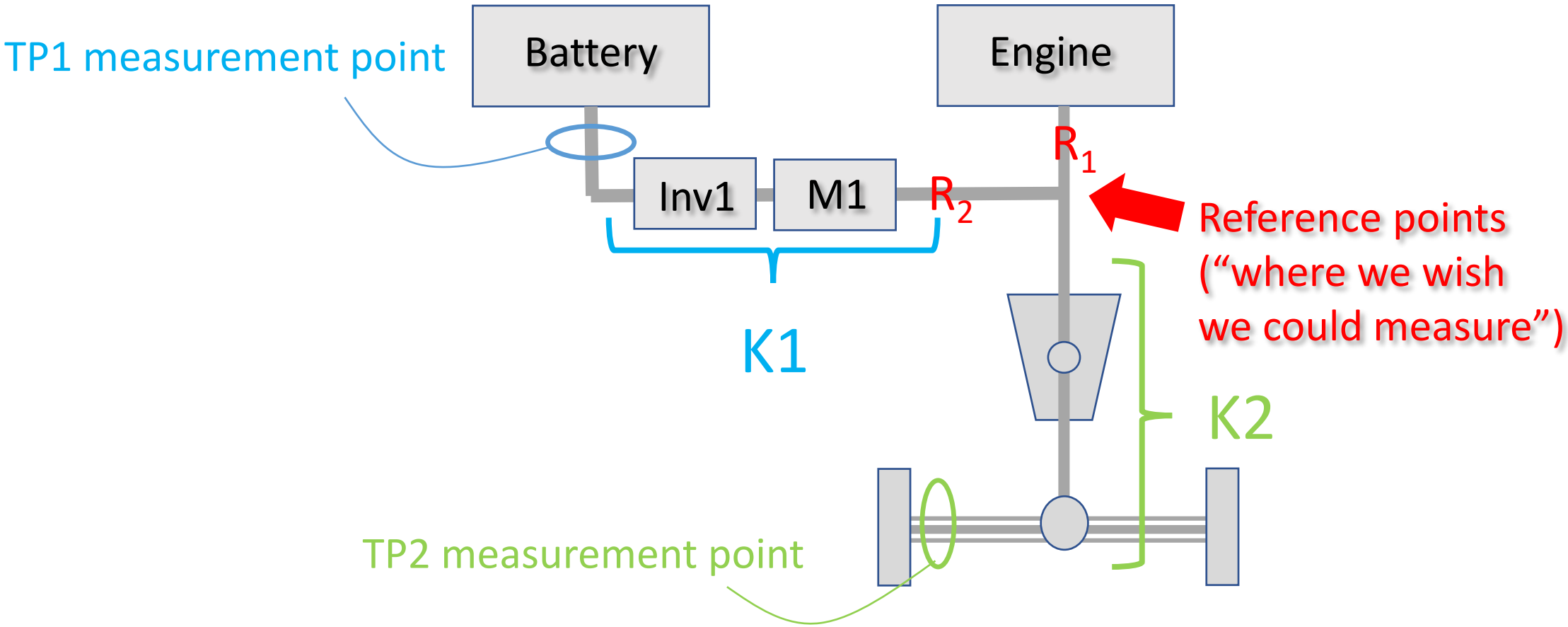
P1 (CISG)



…with an element of P3 or P4

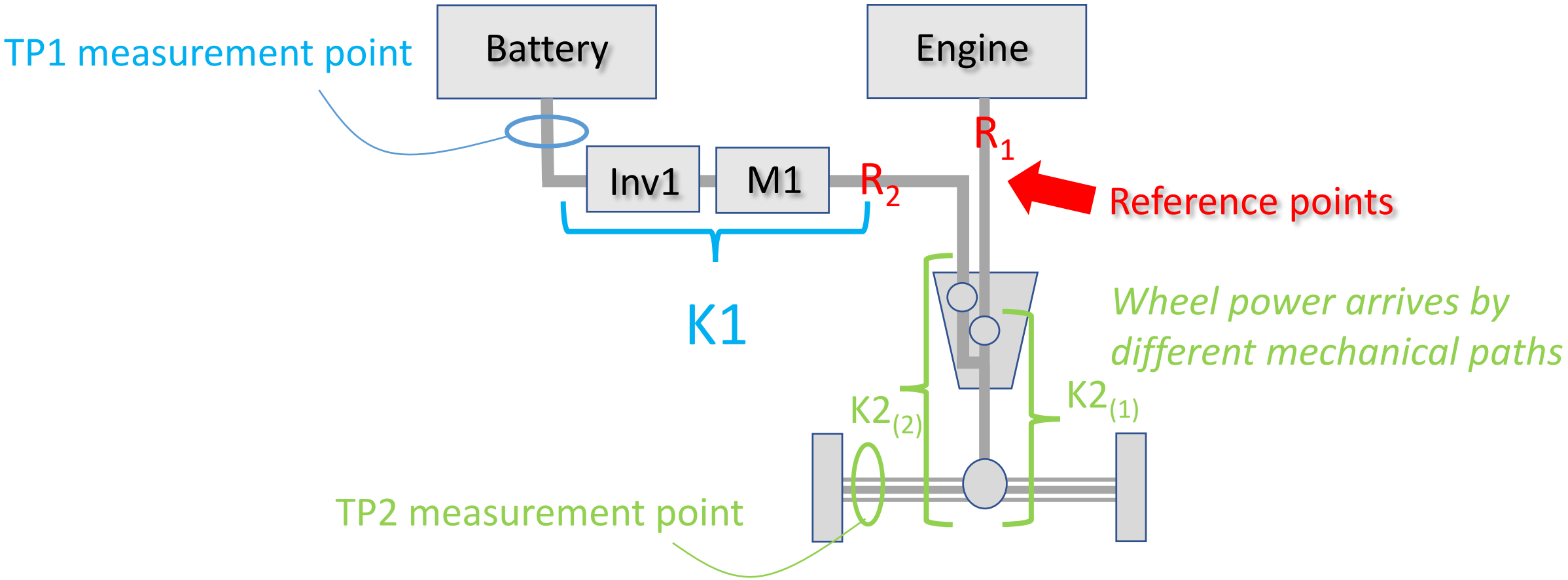
P2 hybrid, 2WD

"Reference point" is a point in the powertrain where we want to know the power. We then add them up.



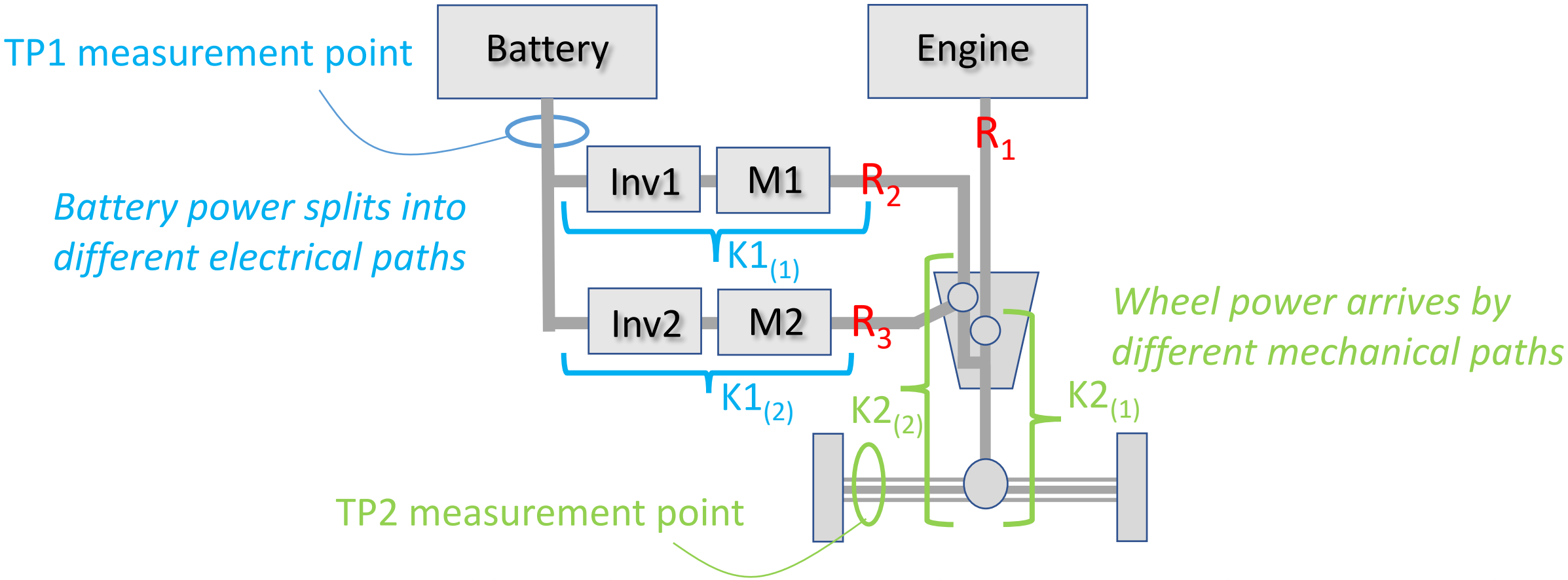
OK: Application of TP1 or TP2 arrives at the same reference point.

Power Split hybrid, 2WD



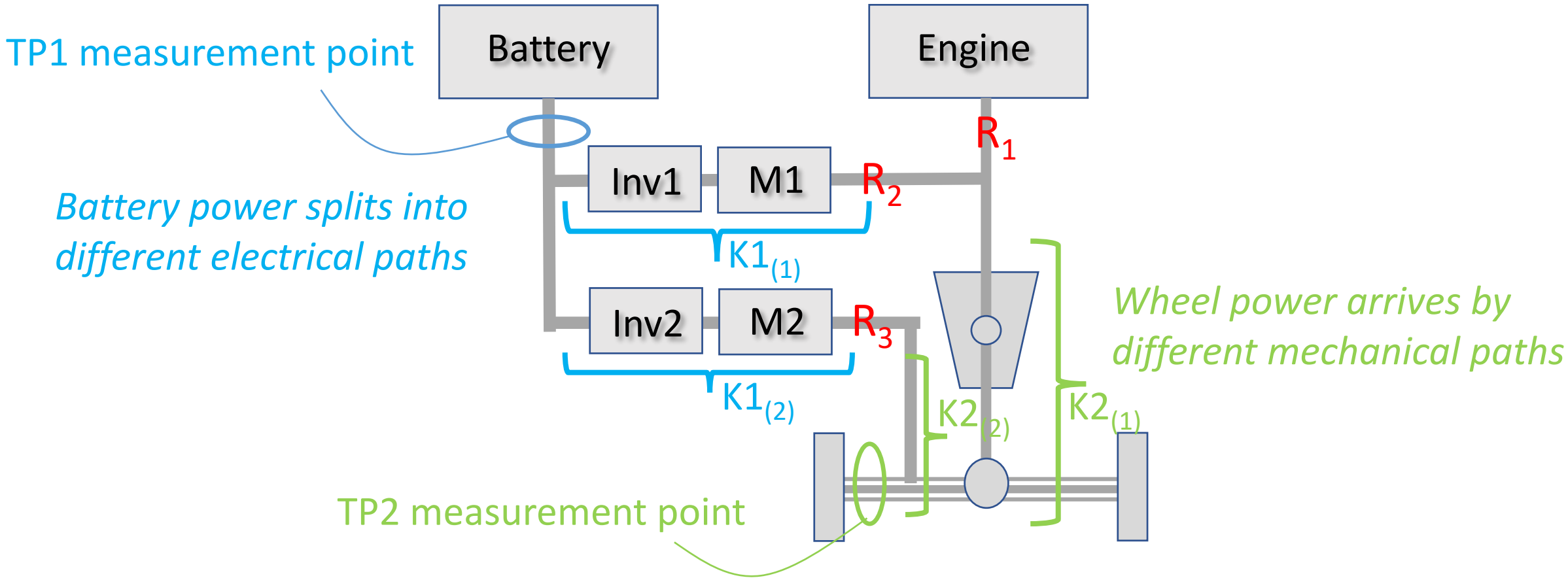
Now the gearbox has two power paths. So TP2 needs to divide the measured wheel power and apply two K2 factors (or use an average K2).

2-motor Power Split hybrid, 2WD



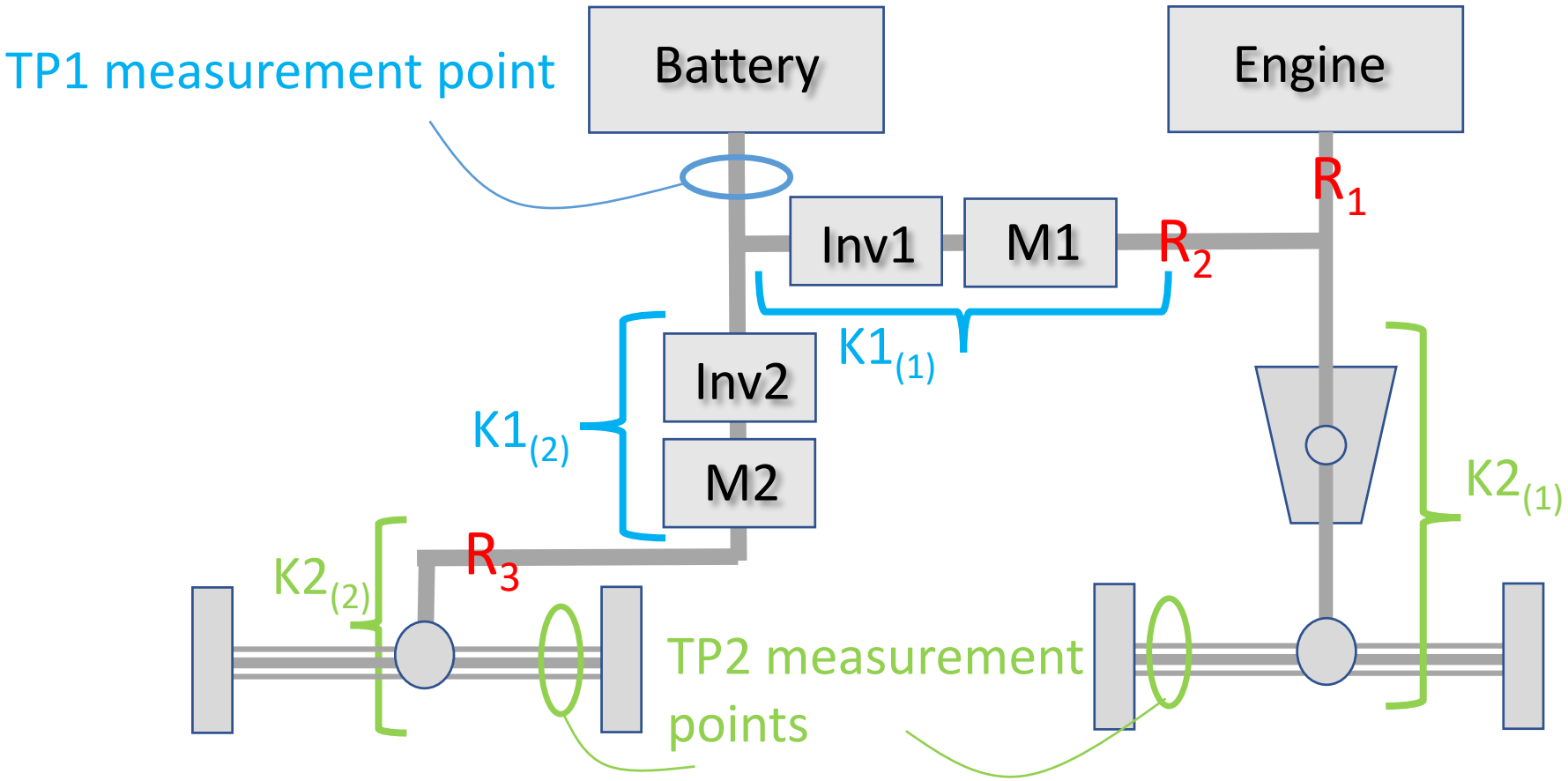
Now TP1 is in trouble too, because measured battery power splits into two paths.
TP1 needs to measure at inverter inputs, and apply two K1 factors.

P2 + P4 hybrid, 2WD



TP1 still needs to measure at each inverter input and apply two K1 factors.
TP2 becomes very difficult: how to divide power, or derive average K2?

P2 + P4 hybrid, 4WD (similar to Volvo T8)



TP2 ok (do each axle separately). But TP1 needs to measure at inverter inputs.

Other considerations

- Some vehicles may not be possible to instrument sufficiently
  - Inverter inputs may be inaccessible
  - Highly integrated components in future?
- For 4WD, is it ok to do TP1 on one axle, and TP2 on another?

Suggestion

- Modify TP1:
  - Instead of “REESS voltage and current”, specify “voltage and current at input to each inverter”
  - If only one inverter, it is the same as measuring at the battery
  - If two or more inverters, more instrumentation is necessary
- Modify TP2:
  - If the combined torque arrives to the axle by more than one mechanical path:
    - Either perform TP1, or
    - Manufacturer must provide an average K2 that applies during the maximum power condition, with an engineering analysis to support it, or
    - Instrument sufficiently to determine torque split and supply K2 factors for each

Example text:

- “The maximum system power may be determined by performing TP1 or TP2, subject to the following requirements:”
- “For each powered axle:
  - If the torque to the axle is provided by a single power-producing component, then the power to the axle may be determined by either TP1 or TP2.
  - Otherwise *[this means that the torque to the axle is a combined torque, provided by more than one power-producing component]*:
    - If the respective torque contributions of each power-producing component are transmitted to the axle via the same mechanical path, the power to the axle may be determined by either TP1 or TP2.
    - Otherwise *[this means that one or more of the individual torque contributions are transmitted to the axle via different mechanical paths]*, the power to the axle shall be determined by either:
      - TP1, or
      - TP2, with the additional requirements:
        - (a) an average K2 representing the net efficiency of the combined mechanical path, and documentation to support; or
        - (b):
          - additional instrumentation by which the proportional torque provided by each power-producing component may be determined, and
          - K2 factors representing the efficiency of the mechanical path followed by the torque from each power-producing component.”