Power determination

Technical Discussion and Proposals

EVE-32, Brussels, October 2019

Requirements of the procedure

- Comparable to traditional engine-based power rating
- Reasonable test burden (instrumentation, flexibility)
- Consistent and repeatable results (prevent “cherry-picking”)
- Verifiable by authority and third parties
- Fair for all hybrid architectures

Comparability

- What do we mean by “comparable”?
  - Traditionally, vehicle power is the rated engine power
  - It represents the power available upstream of the transmission
  - Road power will be less
    - But that doesn’t matter.
    - Traditional measure has always neglected losses in the transmission
- How does ISO 20762 achieve comparability?
  - It represents the power at a “comparable” point in the HEV powertrain: i.e. where torque is first produced, neglecting losses in the gearbox
  - Based on a conversion of upstream or downstream measurements
    - TP1: Measure upstream of “comparable point”
    - TP2: Measure downstream of “comparable point”

Main open issue: Difference in TP1 and TP2

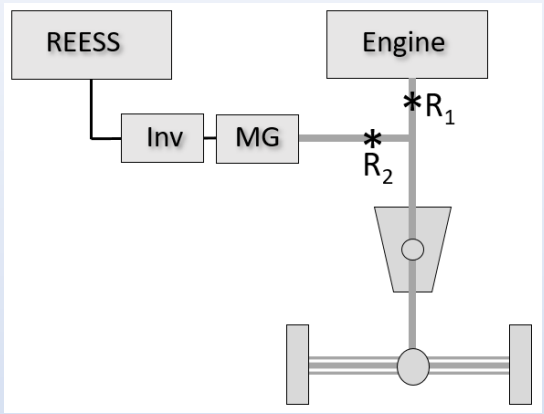
- TP1 and TP2 sometimes give different results
- Some possible causes have been proposed:
  - Use of default K factors, instead of K factors that are accurate for the vehicle
  - TP1: The engine power might not be same as the R85 result
  - TP2: Tire losses and slippage may introduce error
  - Uncertain if TP1 and TP2 are measuring the same thing (same “comparable” point?)
- Proposed solutions:
  - Do not rely on default K factors (manufacturer will provide)
  - Clarify how to confirm R85 engine operation condition (tolerance, fuel flow rate)
  - Use torque and speed sensors for TP2 instead of dyno roller data
  - Make sure TP1 and TP2 are estimating power at the same “comparable” points

New concept: “Reference point”

- Introduced at EVE-31, May 2019 (EVE-31-05e.pdf)
- Premise:
  - There are specific point(s) in an HEV powertrain that are mechanically most analogous to the engine output shaft of a traditional vehicle.
  - The power passing through these point(s) is therefore “comparable” to ICE power.
- ISO 20762 implies a reference point, but does not identify it
- Different HEV architectures and modes will have different reference points!
- Therefore:
  - The procedure should establish the reference points
  - TP1 and TP2 should use the same reference points

Examples of reference points

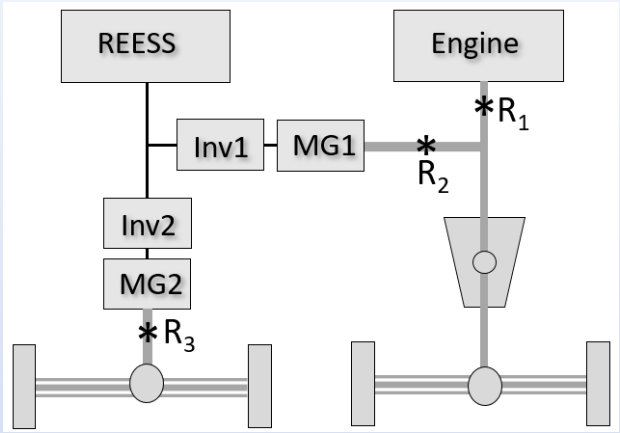
P2 parallel HEV



System power = R1+R2

- TP1 and TP2 easily reach the same reference points.

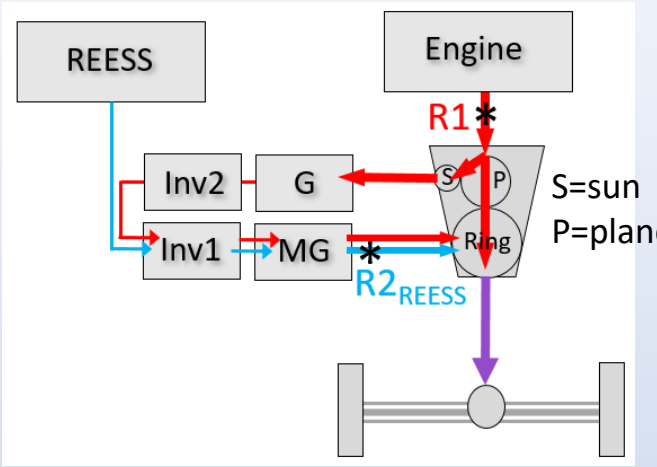
HEV with P2 and P4 (Volvo XC60 T8)



System power = R1+R2+R3

(4WD dyno needed.)
- TP2 is straightforward.
- TP1 may need to instrument both inverters.

Power split HEV



System power = $R1+R2_{REESS}$

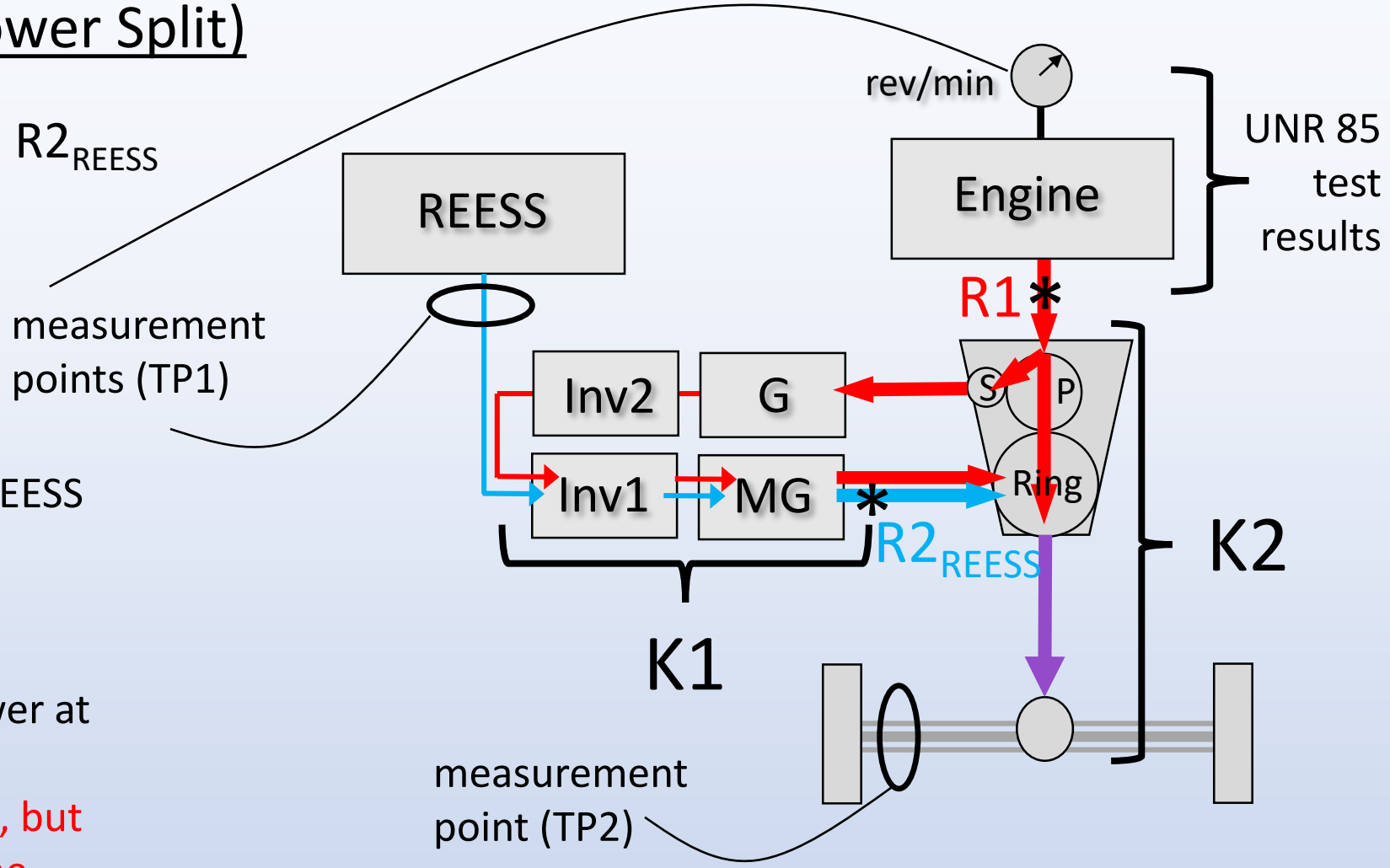
- TP1 is straightforward.
- TP2 does not collect enough information to reconstruct R1 and $R2_{REESS}$

HEV architecture and modes

- In the current version of the procedure, the reference points for TP1 and TP2 are not explicitly defined
  - Reference points are implied by the measurements and calculations
- The following slides show how:
  - Sometimes the reference points for TP1 and TP2 are not the same
  - The situation varies by HEV architecture
  - Differences in operating mode can also result in changes to the reference points, and the applicability of TP1 or TP2

Toyota Hybrid System (Power Split)

Reference points are R1 and $R2_{REESS}$



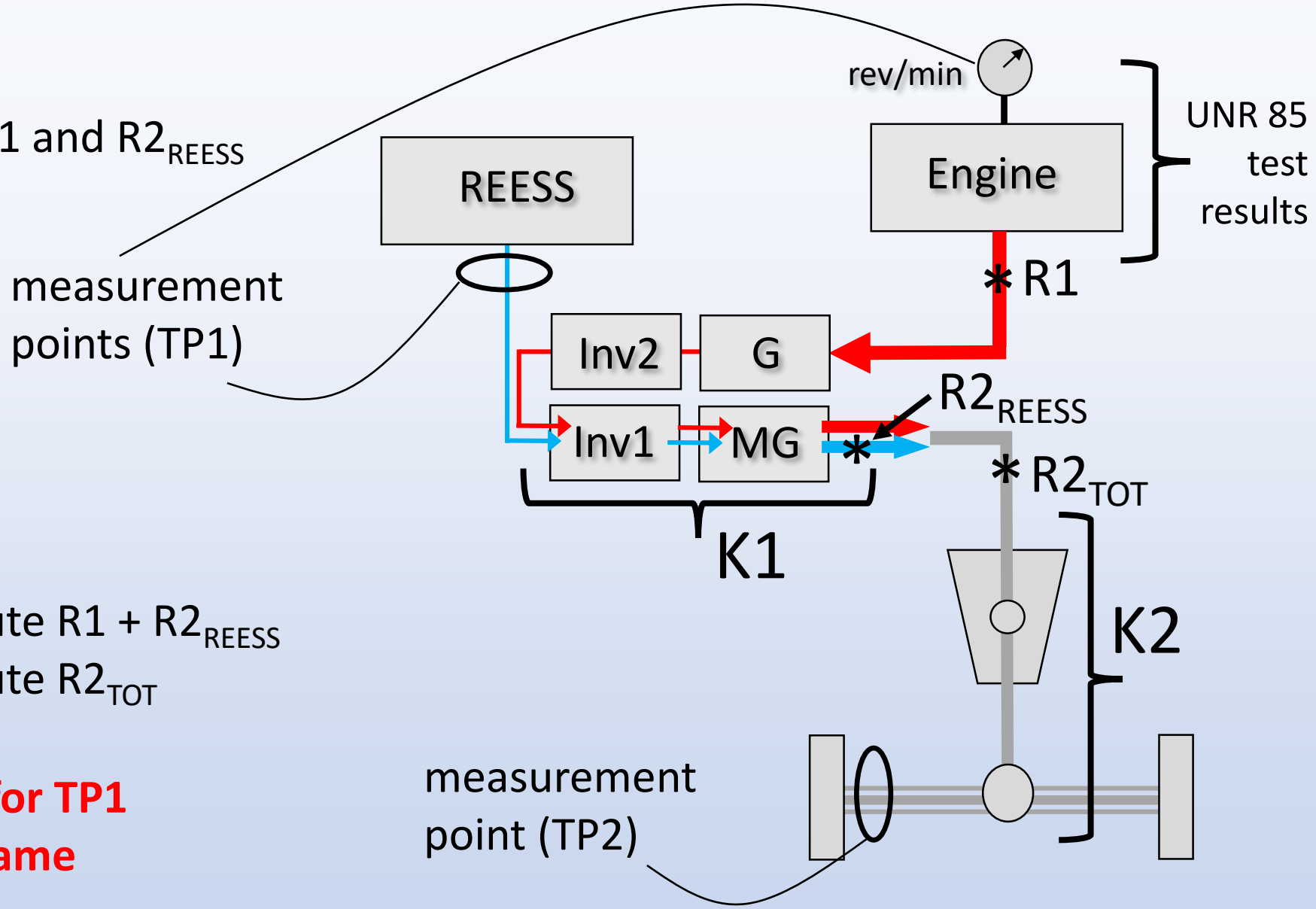
ISO 20762 as currently performed:

- TP1 would measure engine and REESS power, and compute R1 + $R2_{REESS}$
- TP2 would measure power at the wheels and apply K2=0.93
- Not clear if this results in the power at the same reference points as TP1
- TP2 could construct [R1 + $R2_{REESS}$], but only if efficiency of all paths on the way to the wheels is the same (it is not)

i.e. Reference points for TP1 and TP2 are not the same

Pure series HEV

Reference points are R1 and $R2_{REESS}$



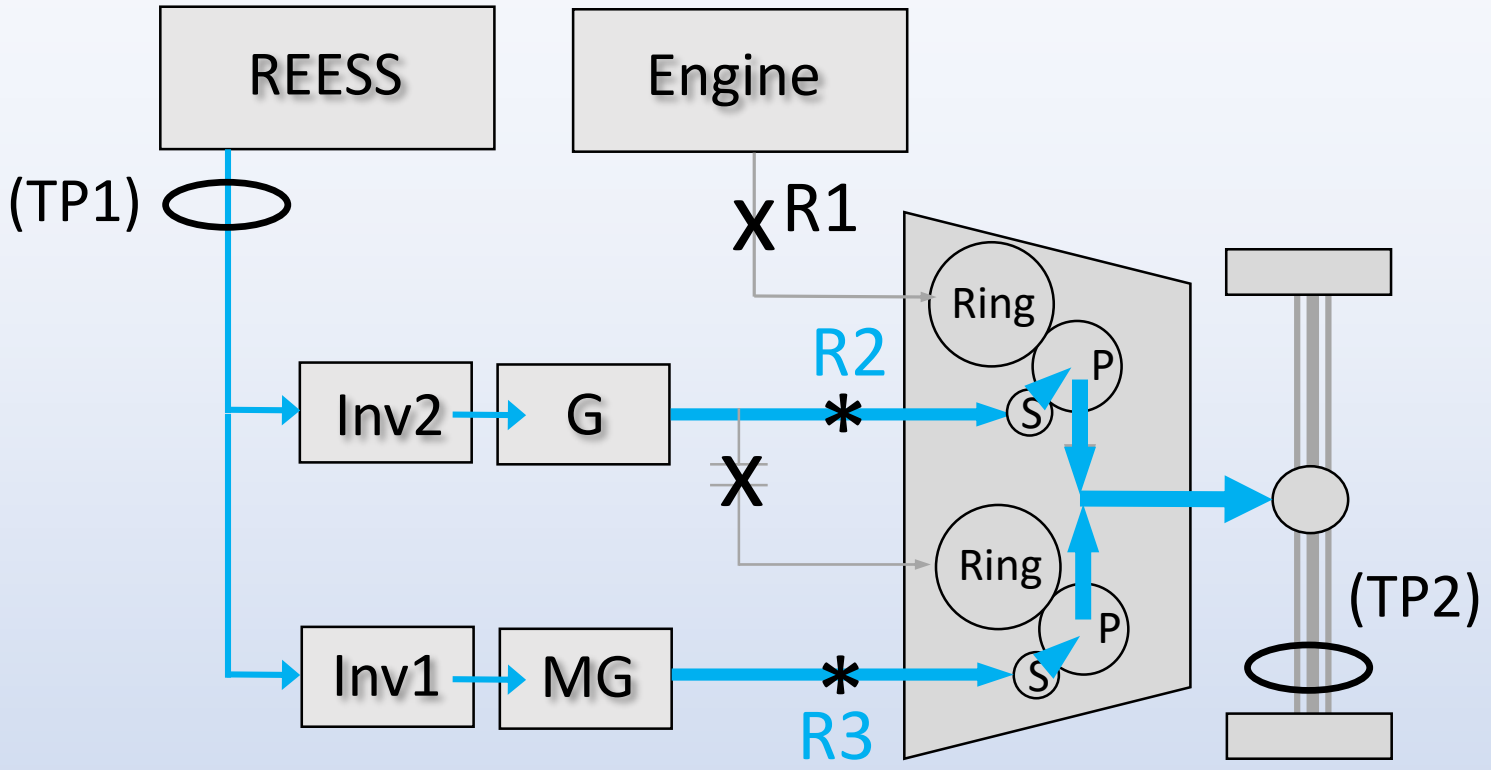
ISO 20762 as currently performed:

- TP1 would compute R1 + $R2_{REESS}$
- TP2 would compute $R2_{TOT}$

i.e. Reference points for TP1 and TP2 are not the same

Volt Gen 2 (all electric – CD2 mode)

Reference points are R2 and R3



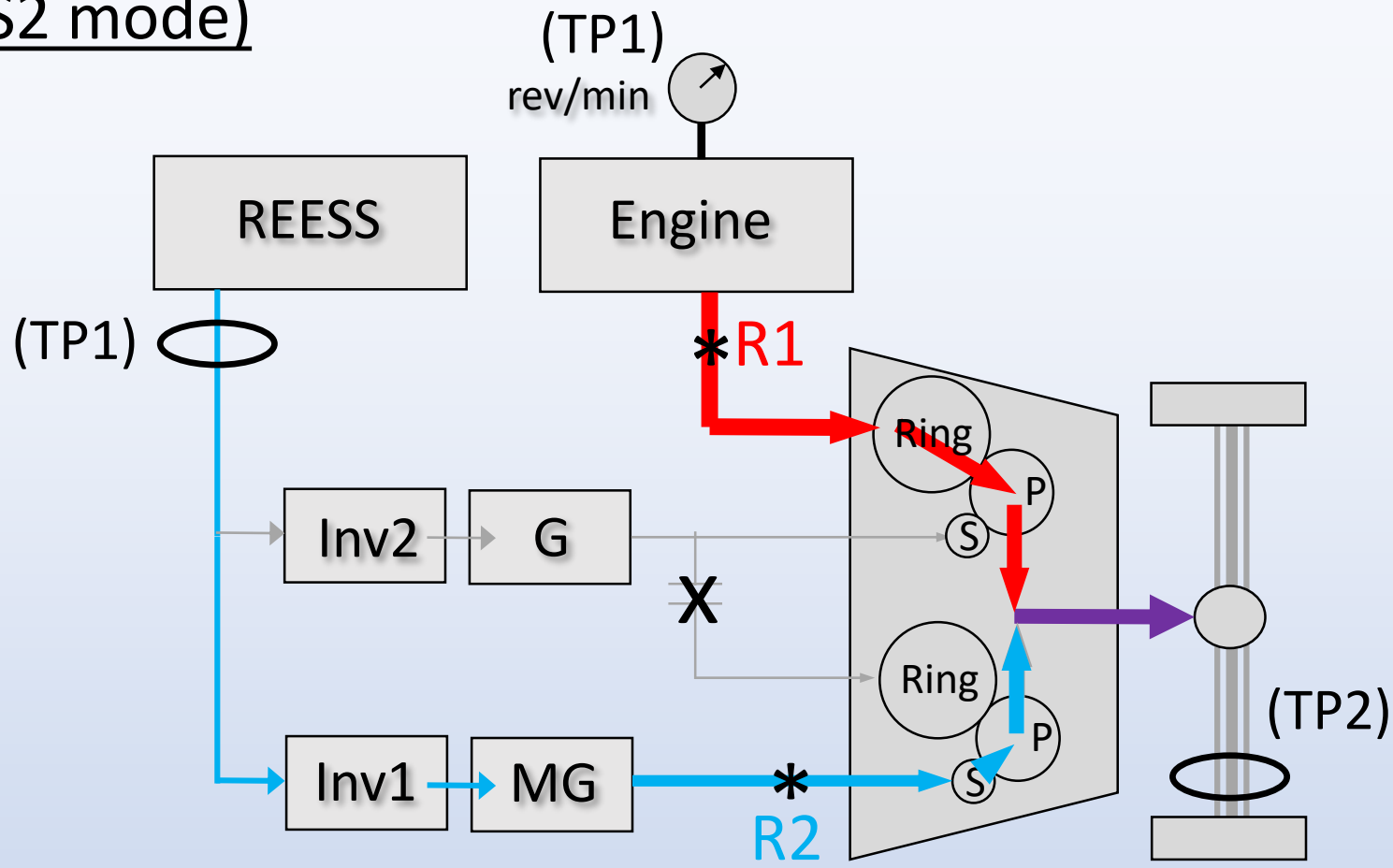
TP2: can determine sum [R2+R3] (if efficiency of both S→P is the same)

TP1: maybe (if you measure at both inverters, or both paths have same efficiency)

Volt Gen 2 (engine in use – CS2 mode)

Reference points are R1 and R2

- Change in operating mode leads to change in reference points and potential applicability of TP1 or TP2



TP1: easily determines R1 and R2

TP2: maybe can determine sum [R1+R2] (if efficiency of R→P and S→P are the same)

Establishing the reference points can solve many problems

- Comparability:
  - Provides clear theoretical basis for comparability to ICE power
- Reasonable test burden:
  - Preserves ability to perform TP1 or TP2 (where both are possible)
  - Provides clear basis for inapplicability of TP1 or TP2 to a given powertrain
- Consistent results:
  - If TP1 and TP2 use the same reference points, they should be consistent as long as the measurements and assumptions are accurate
- Verifiable by responsible authority and third parties
  - If TP1 and TP2 use the same reference points, then TP1 = TP2 (all things being equal)
  - “TP1 = TP2” opens path for verification via K factors
- Fair for all hybrid architectures
  - Each HEV has the most “comparable” reference point that its architecture allows

Reference points and “candidate method”

- Candidate method was envisioned as alternative to chassis testing
- Based on analysis of component layout and efficiencies
- Establishing the reference points in the context of the HEV powertrain layout makes it clearer how to perform the analysis
- GTR proposes that the manufacturer provide a hybrid power flow description (schematic) that shows the power flow during maximum power, and the proposed reference points

Recommended additions to GTR

See GTR draft text and Section E.1 (differences between GTR and ISO 20762)

- Introduce and define the concept of “reference point”
- Establish the reference points for common configurations
- Make it clear that:
  - System power is the power that would be measured at the reference points
  - The purpose of the measurements and K factors is to reconstruct the power at the reference points using available measurements
  - TP1 and TP2 are to use the same reference points
- For some architectures, it is natural that TP1 or TP2 may be unable to reconstruct the power at the reference point
- In these cases, specify the TP that works best
  - Determined based on powertrain characteristics (power flow to axle, and number of inverters)
- Examples:
  - Simple parallel P2 HEV → use either TP1 or TP2
  - Power split → use TP1
  - Multiple motors powered by REESS → TP2, or else TP1 must instrument inverter inputs

Main differences between ISO 20762 and GTR

See Section E.1 of draft GTR for details

- E.1.1 Measurement accuracies aligned with GTR No. 15
- E.1.2 Manufacturer to provide K factors (eliminate defaults)
- E.1.3 TP2 to require torque/speed sensors or hub dynamometer
- E.1.4 TP1 to include measurement of fuel flow rate (with tolerance)
- E.1.5 TP1 recommended to measure power at each inverter (if REESS powers multiple inverters)
- E.1.6 Repetition and averaging (average last four of five repetitions)
- E.1.7 Establishment of designated reference points
- E.1.8 Applicability of TP1 or TP2 determined by powertrain characteristics

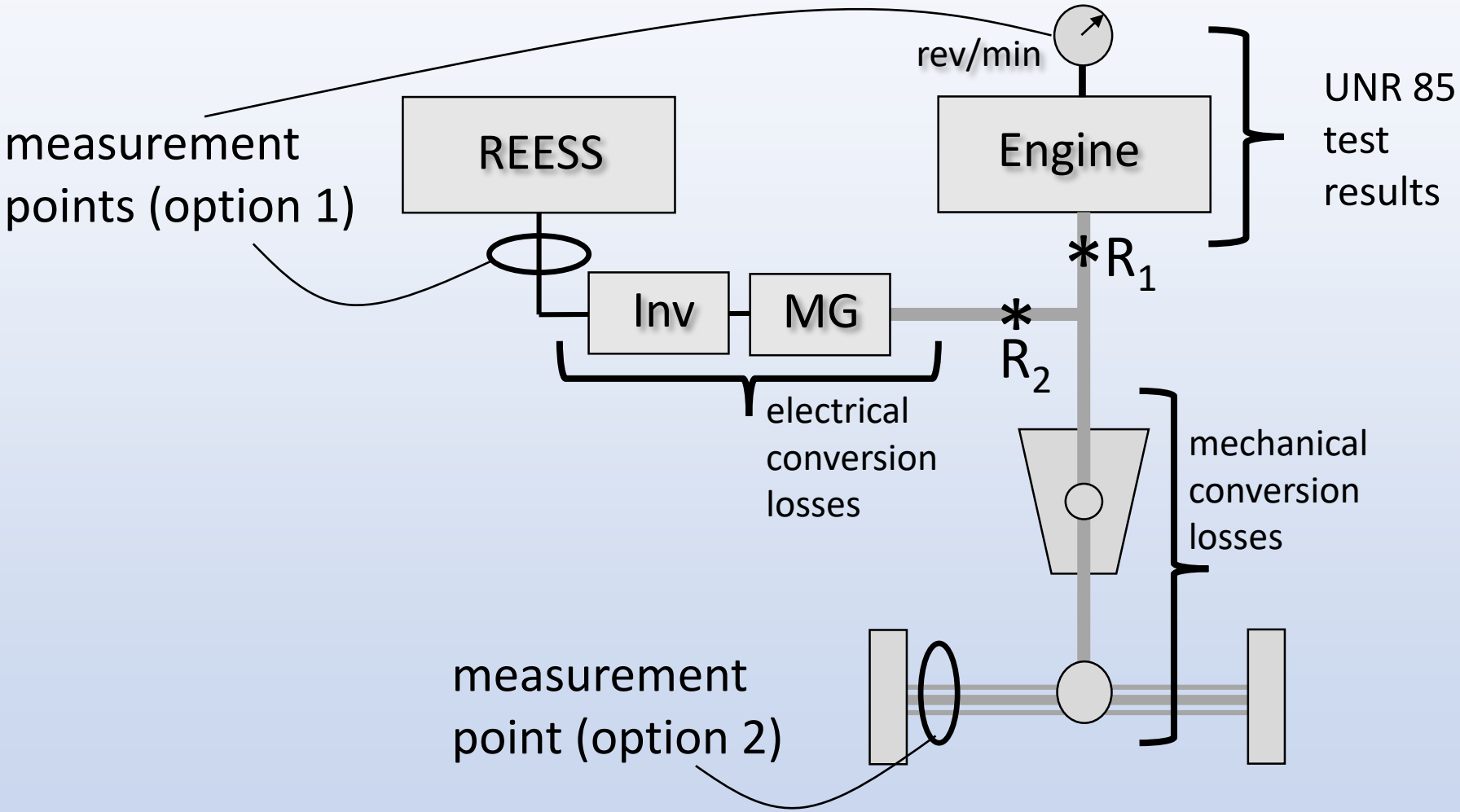
Differences (continued)

- E.1.9 Manufacturer to provide hybrid power flow description
- E.1.10 All-wheel drive vehicles to be evaluated on axle-by-axle basis
- E.1.11 Suggested internal validation criteria
- E.1.12 New terms related to system power determination

Conclusions

- Resolution of open issues seems to be within reach
  - Establishing reference points resolves many of these issues
  - Some HEV configurations may support only TP1 or only TP2
  - The basis for such a conclusion always has a clear technical justification
- Seeking consensus on all issues and their proposed solutions
  - See EVE-32-06e.xlsx
- Implementing the changes will require very careful drafting between now and January 2020
- Basis of validation will shift away from showing that TP1 = TP2, because sometimes only one is applicable
- The primary goal is to show that the procedure is practicable and leads to an unambiguous result

Backup


measurement
points (option 1)
REESS
rev/min
Engine
UNR 85
test
results
*R1
Inv
MG
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R2
electrical
conversion
losses
mechanical
conversion
losses
measurement
point (option 2)