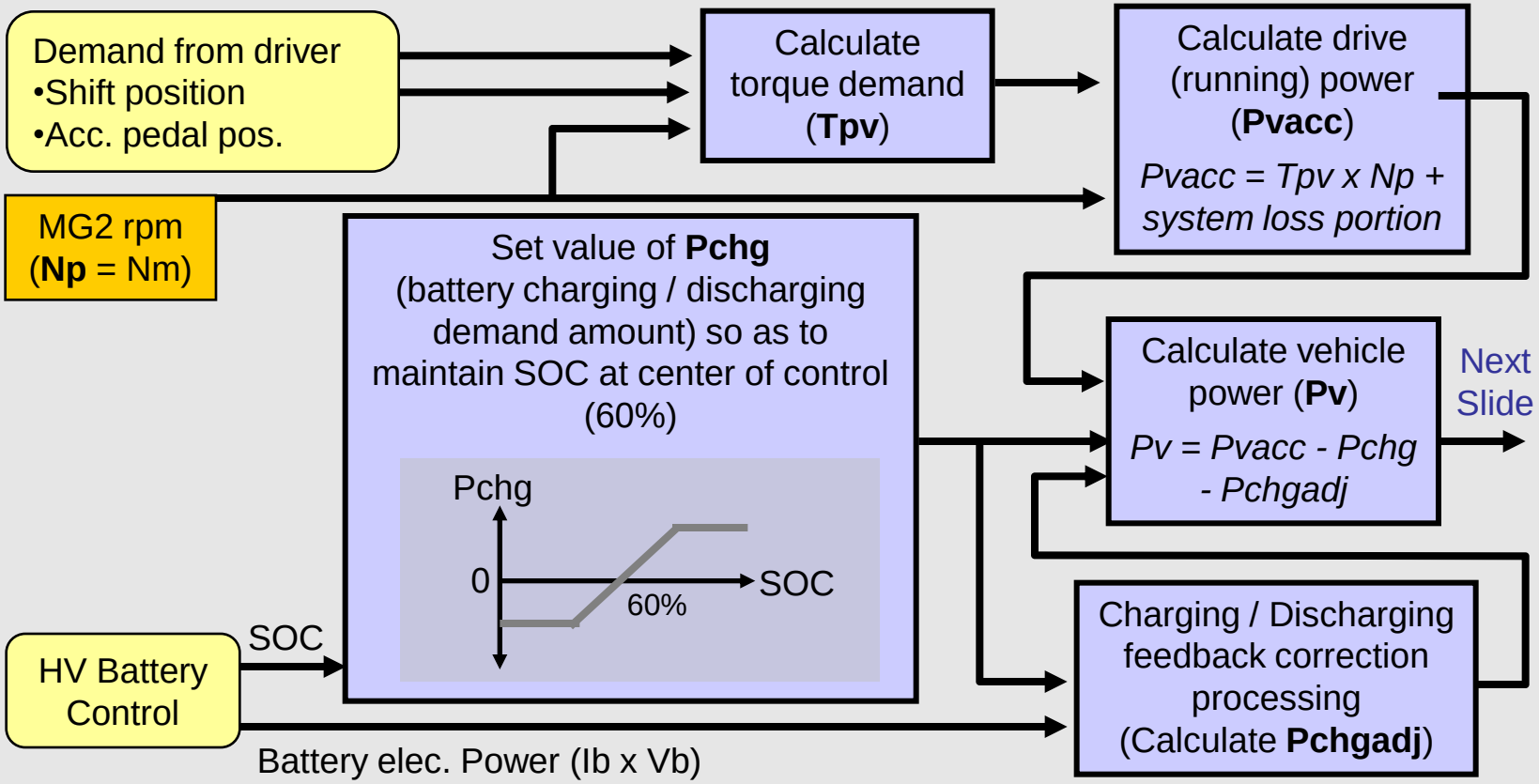
HV & THS Control

Prius vs. RX400h

TOYOTA

Output Calculation

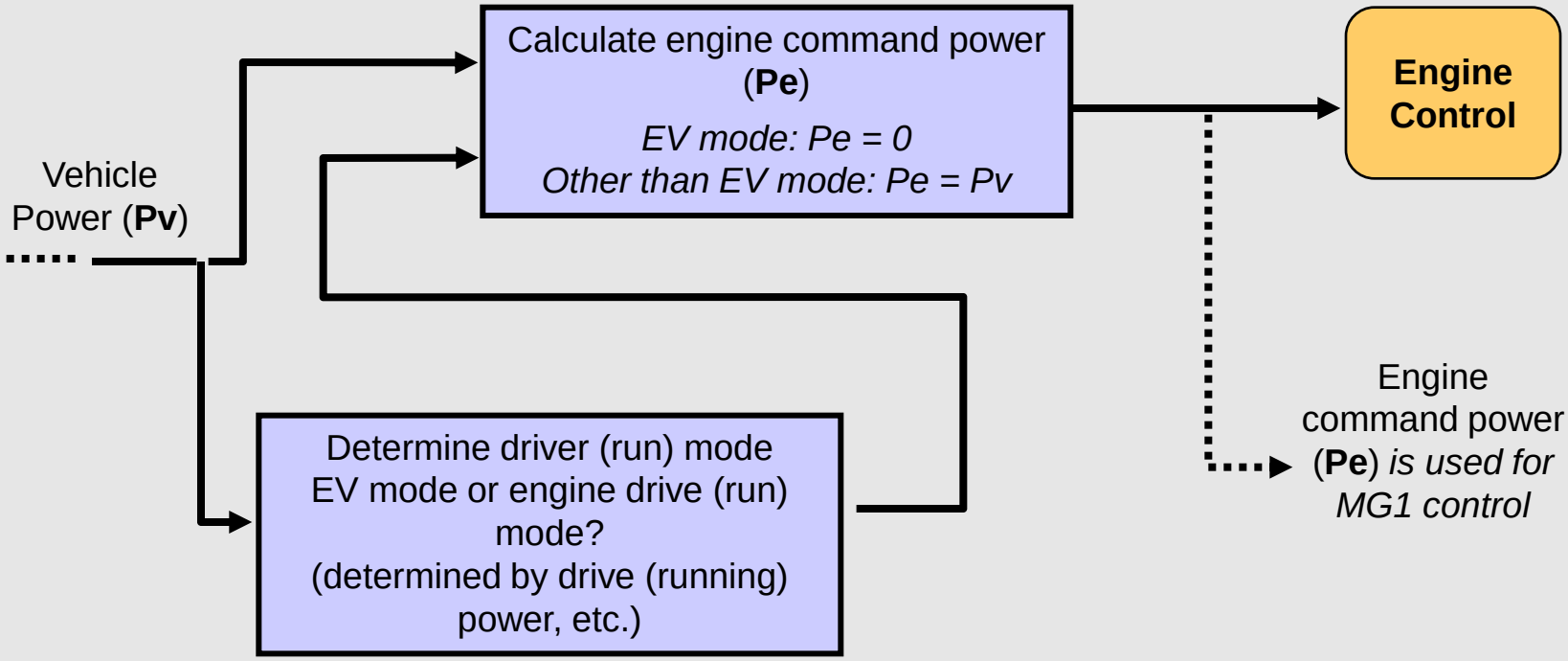
- Engine Control



TOYOTA

Output Calculation

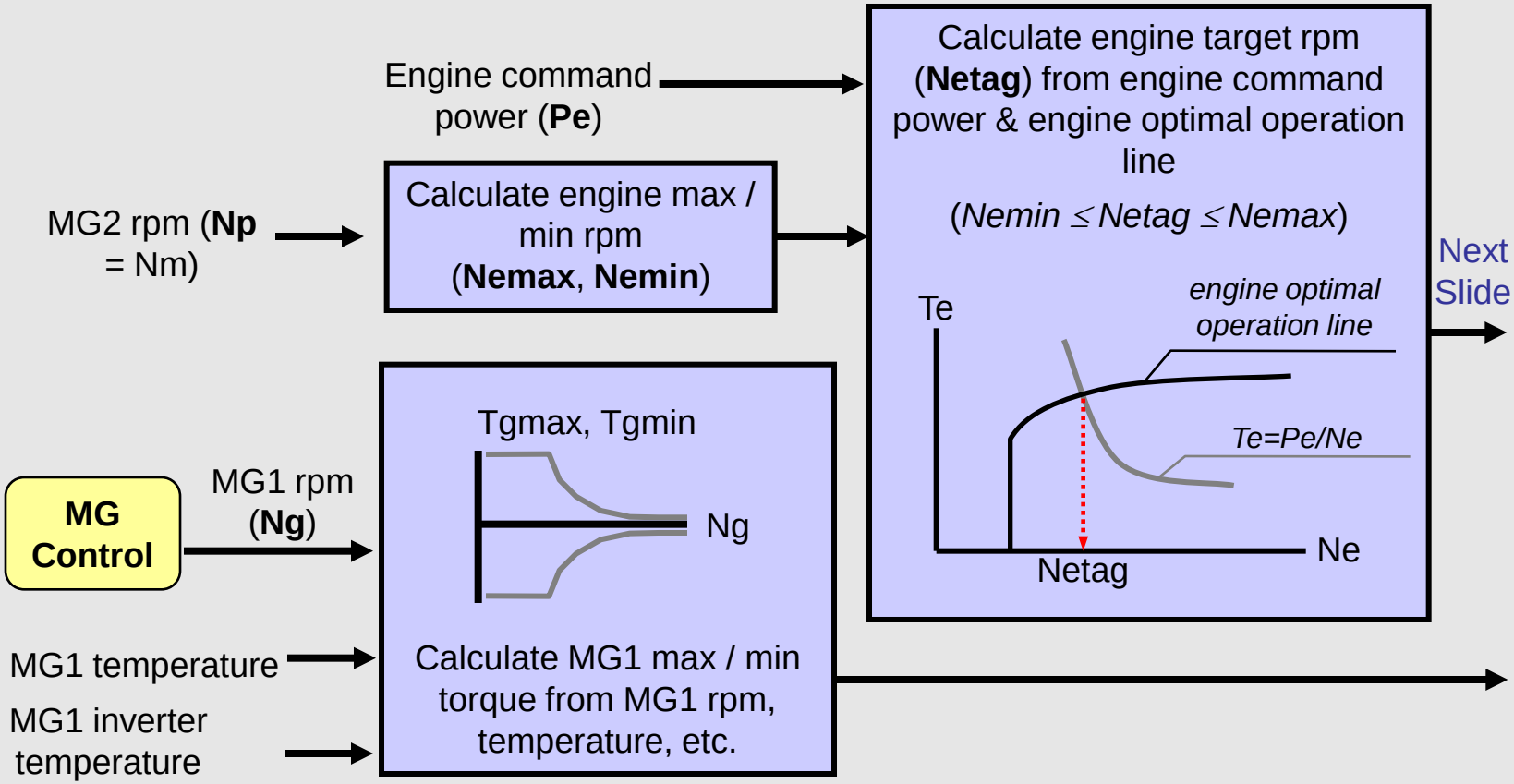
- Engine Control



TOYOTA

Output Calculation

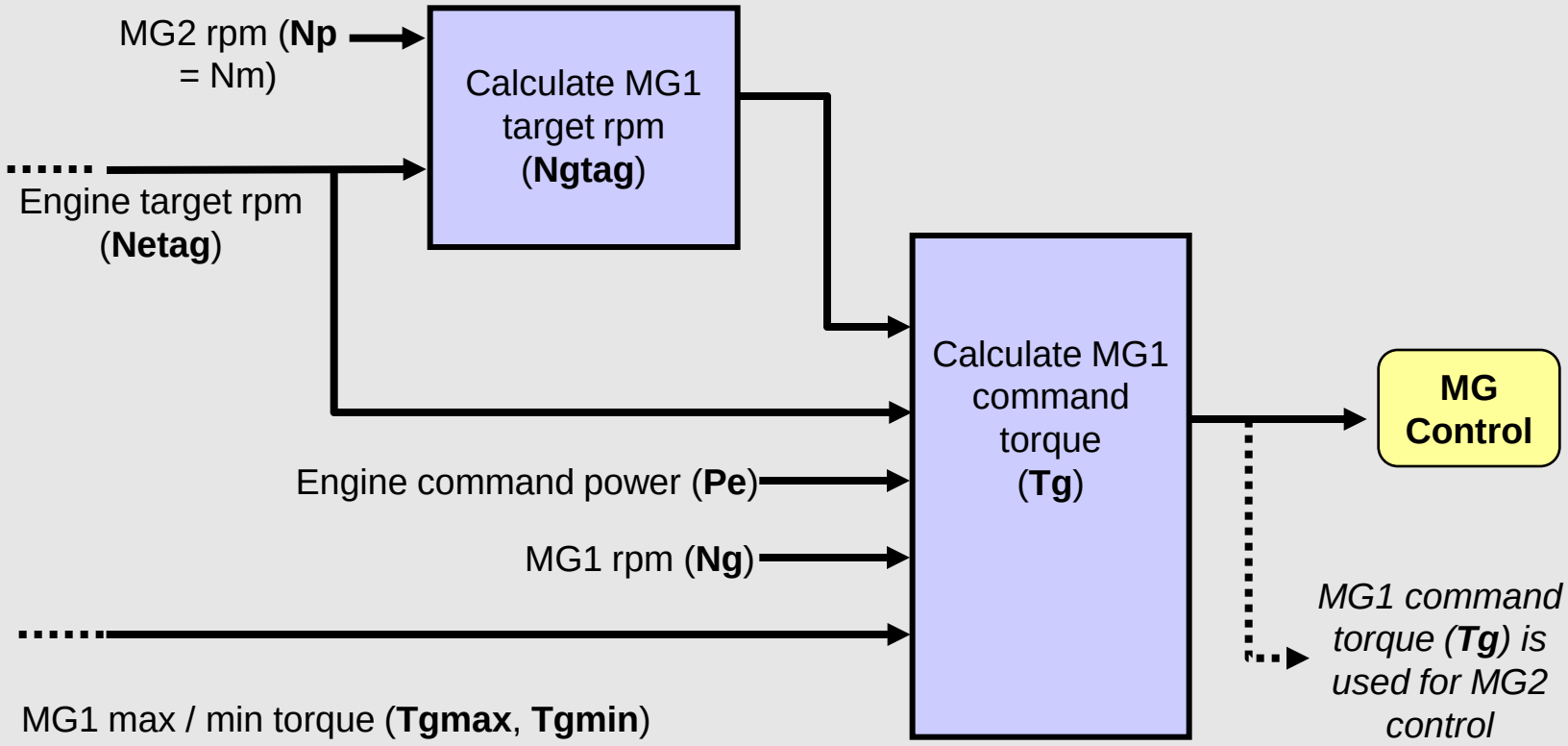
- MG1 Control



TOYOTA

Output Calculation

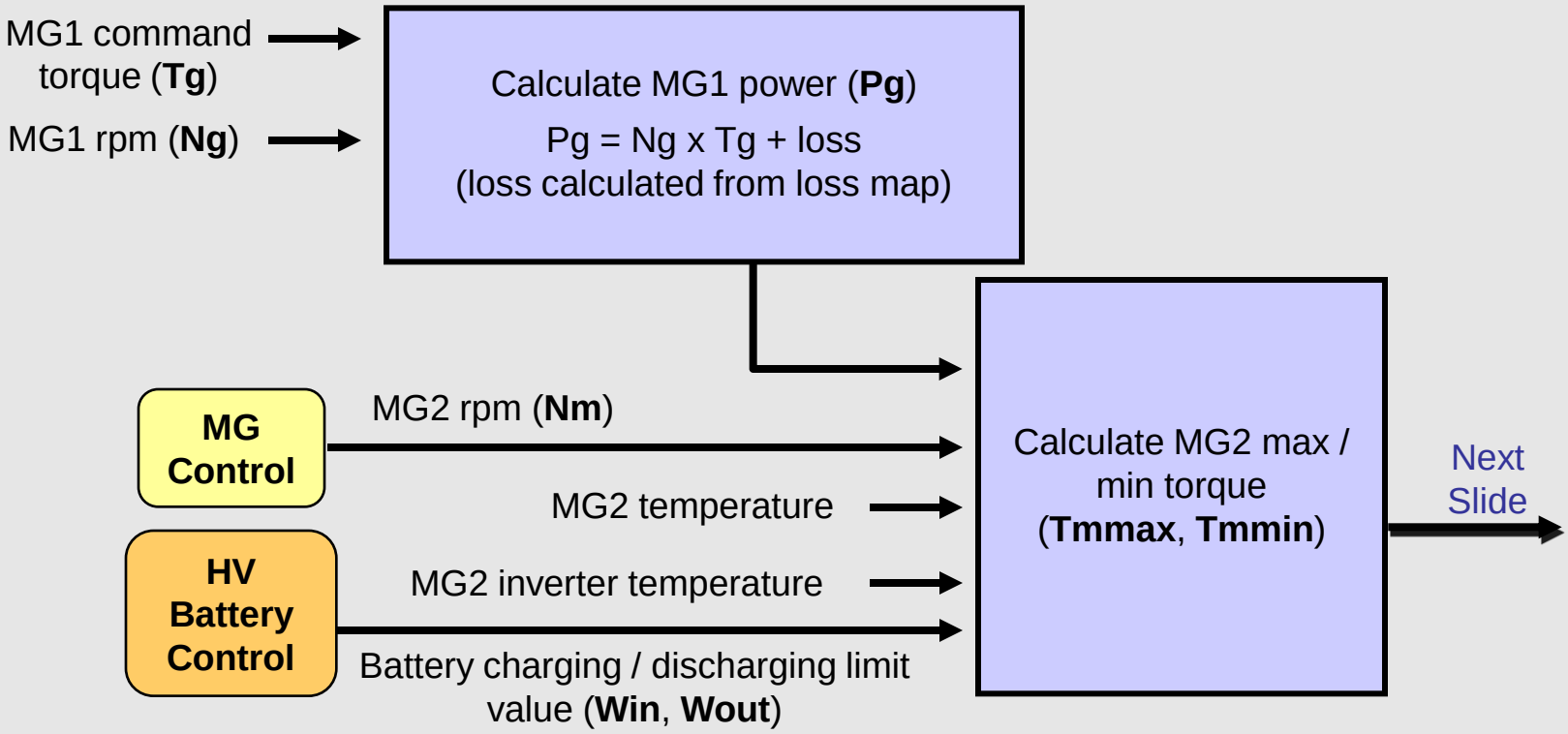
- MG1 Control



TOYOTA

Output Calculation

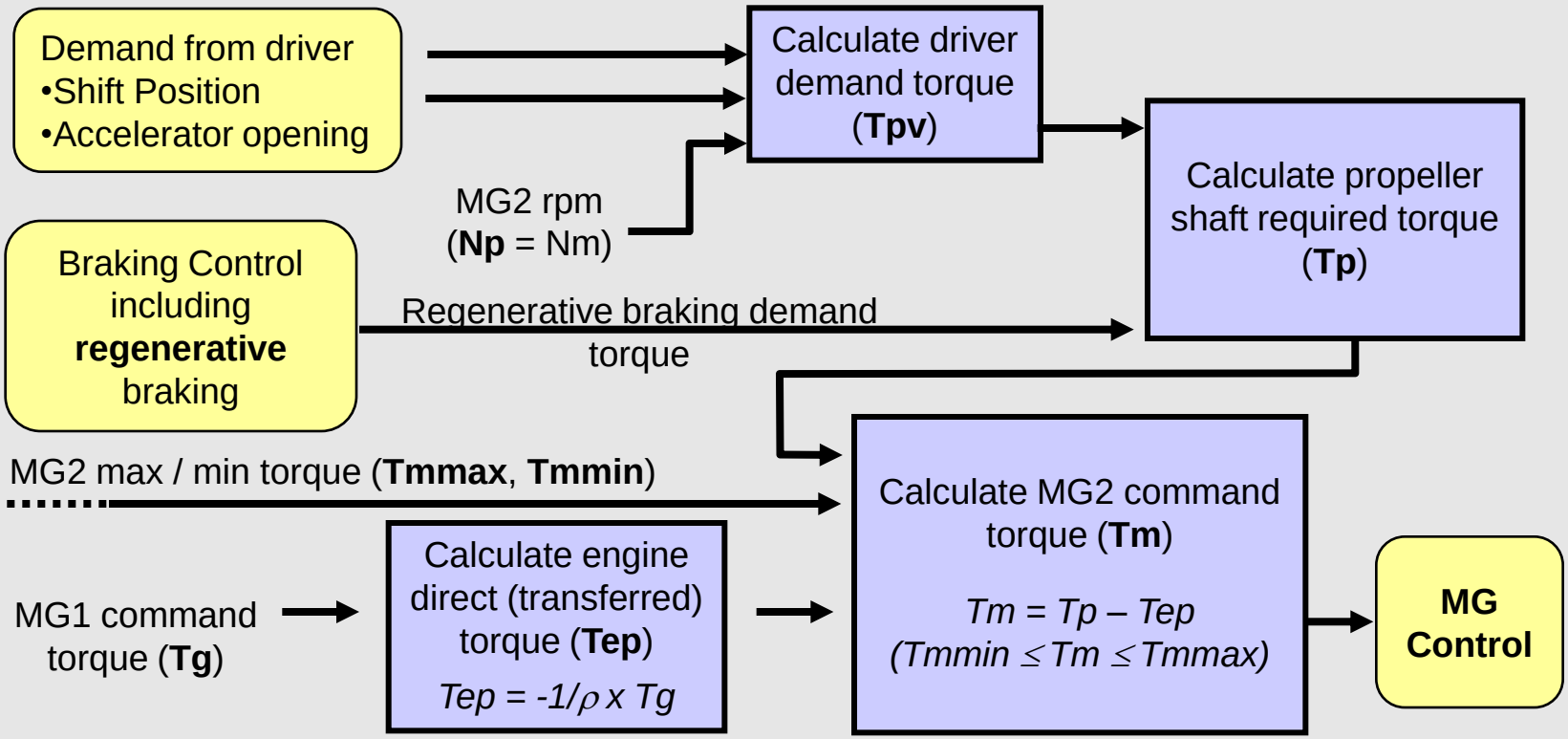
- MG2 Control



TOYOTA

Output Calculation

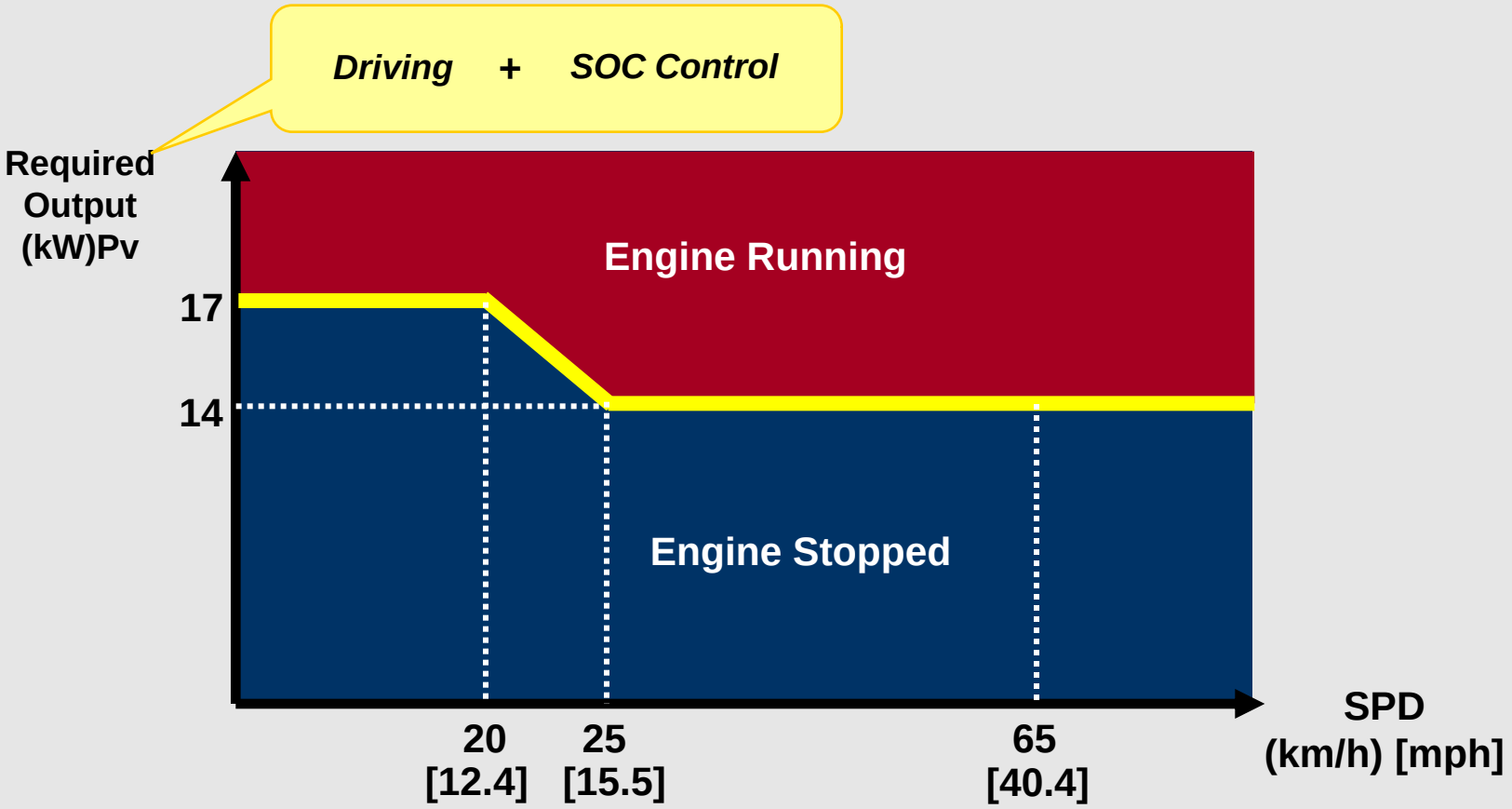
- MG2 Control



TOYOTA

Engine Start Condition

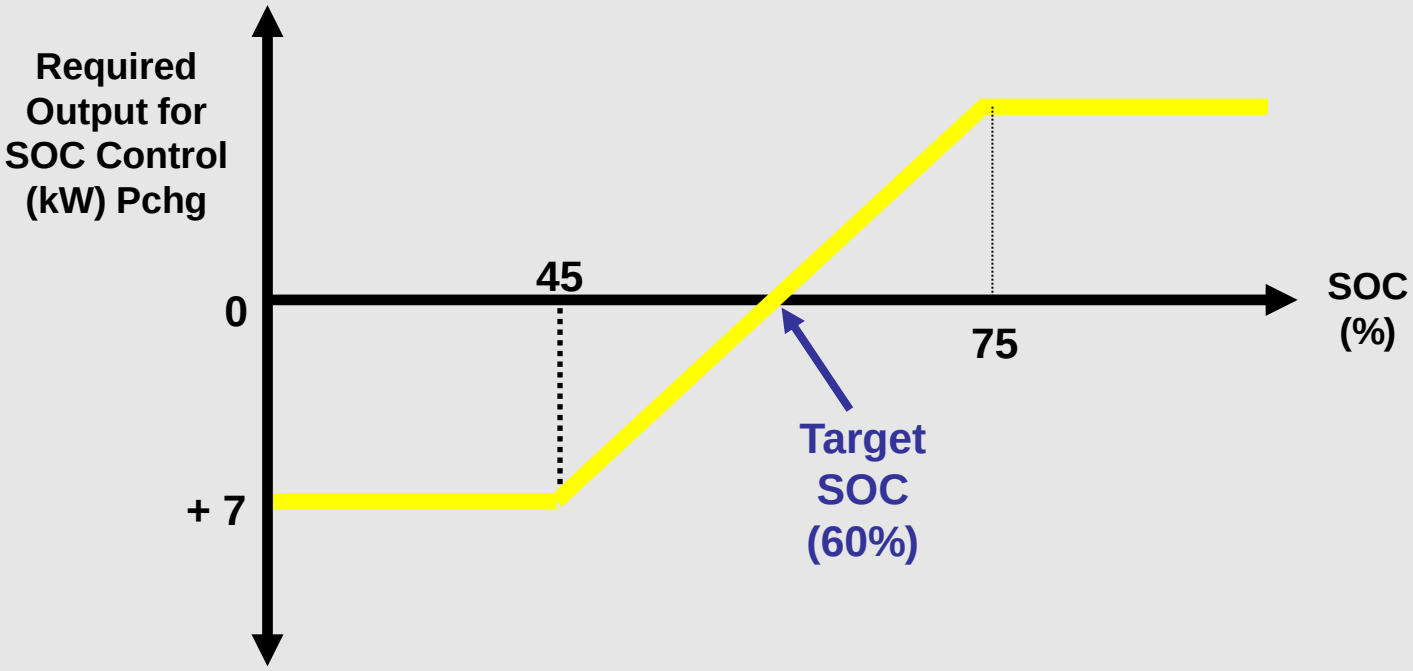
- At Driving



TOYOTA

Engine Start Condition

- Required output for SOC control

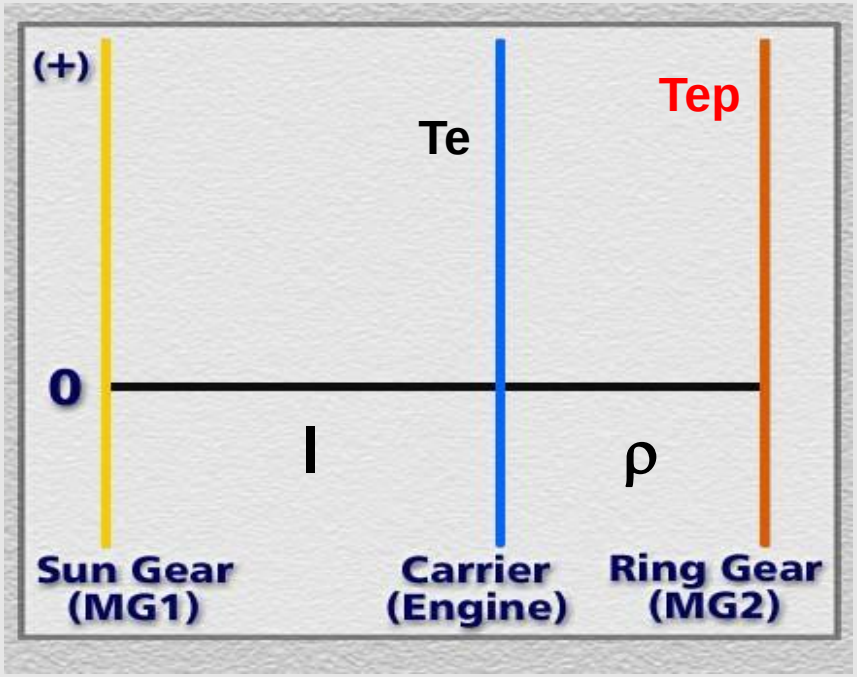


TOYOTA

Nomographic Chart

- General
  - Engine torque is transferred to the ring gear (tire) as a driving force via the planetary gear unit

Engine Direct (Transferred) Torque



Engine Direct (Transferred) Torque

$$Tep = I / (I + \rho) \cdot Te$$

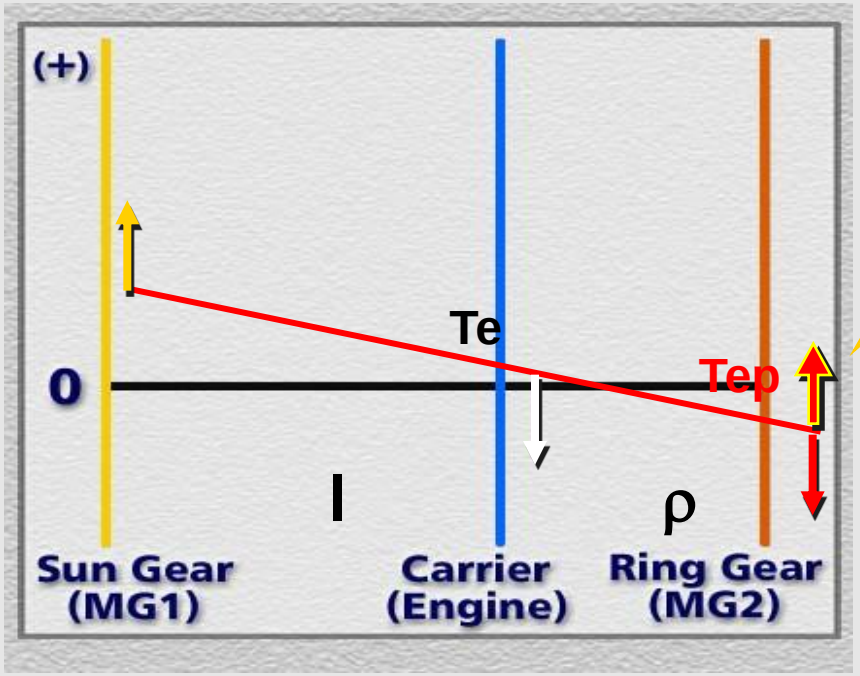
$$\rho = 0.3836$$

- Electric power generated by the MG1 is supplied to the MG2
- HV Battery makes up for energy shortage

TOYOTA

Nomographic Chart

- Reaction Force
  - When the engine starting, the MG1 drives the engine, and the reaction force transmitted to the ring gear (tire)



Cancel the reaction force

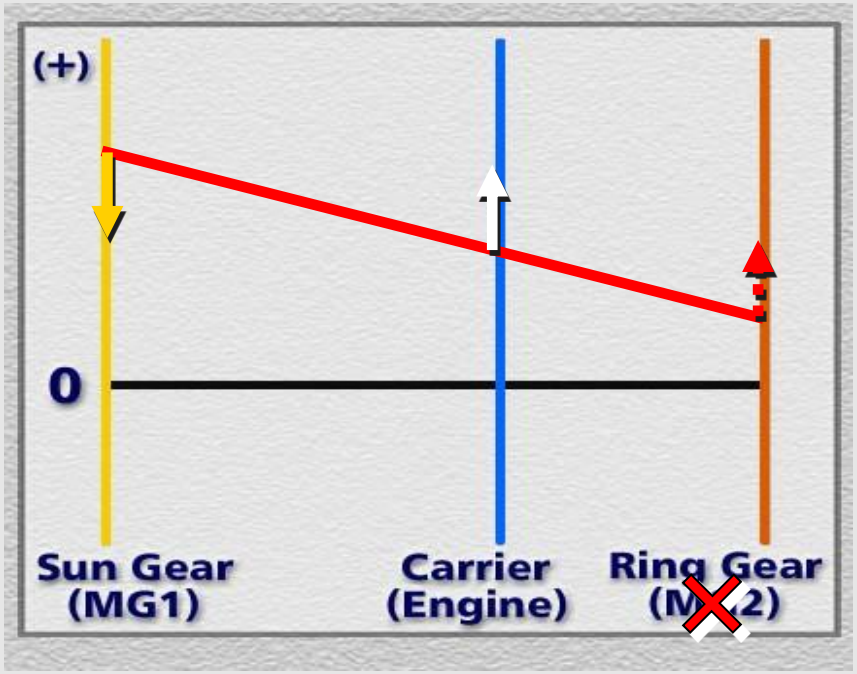
Shock is generated in the vehicle

The MG2 torque is generated to cancel the reaction force

TOYOTA

Nomographic chart

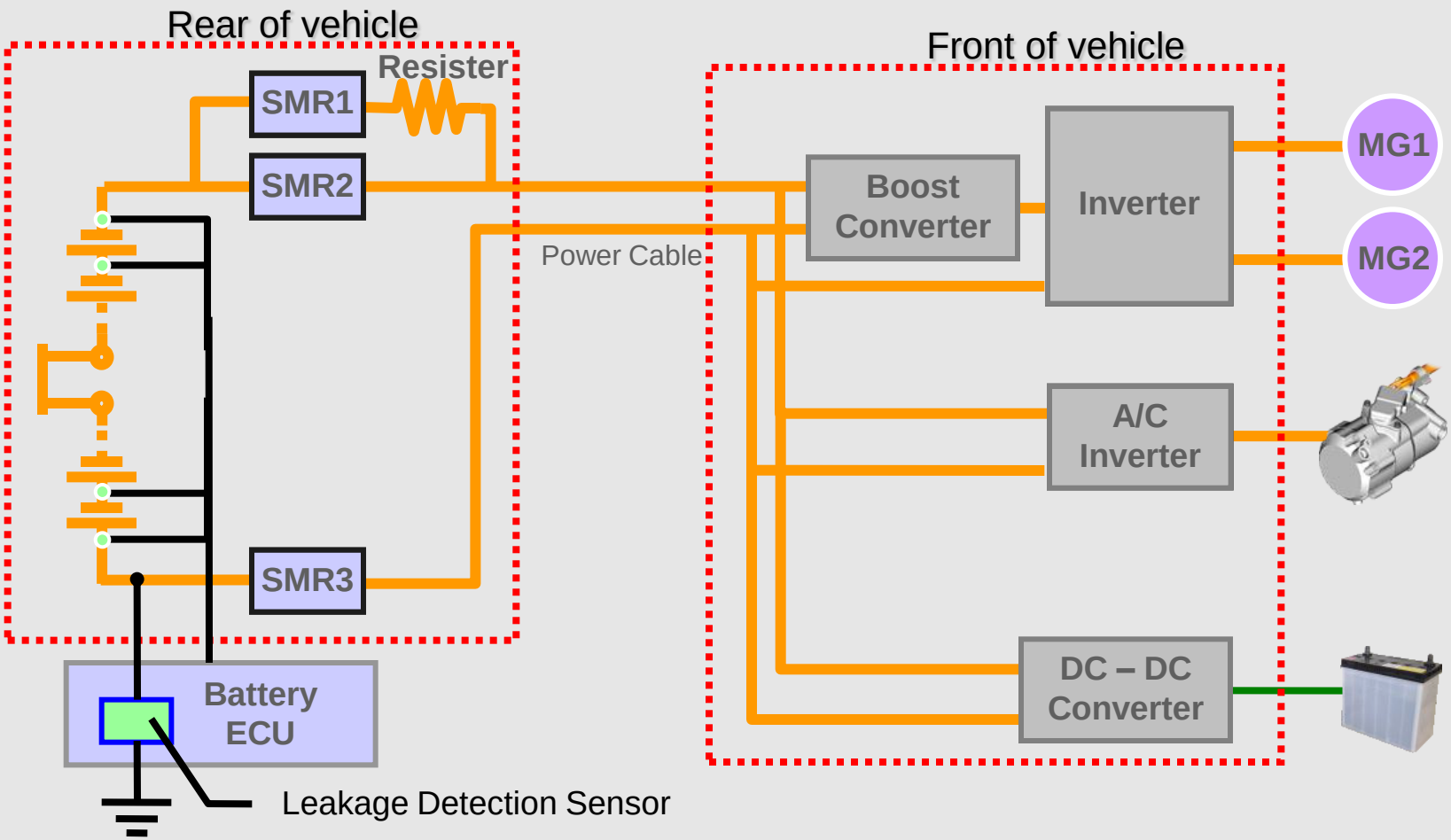
- Example
  - MG2 malfunction



Driven by Engine and MG1

TOYOTA

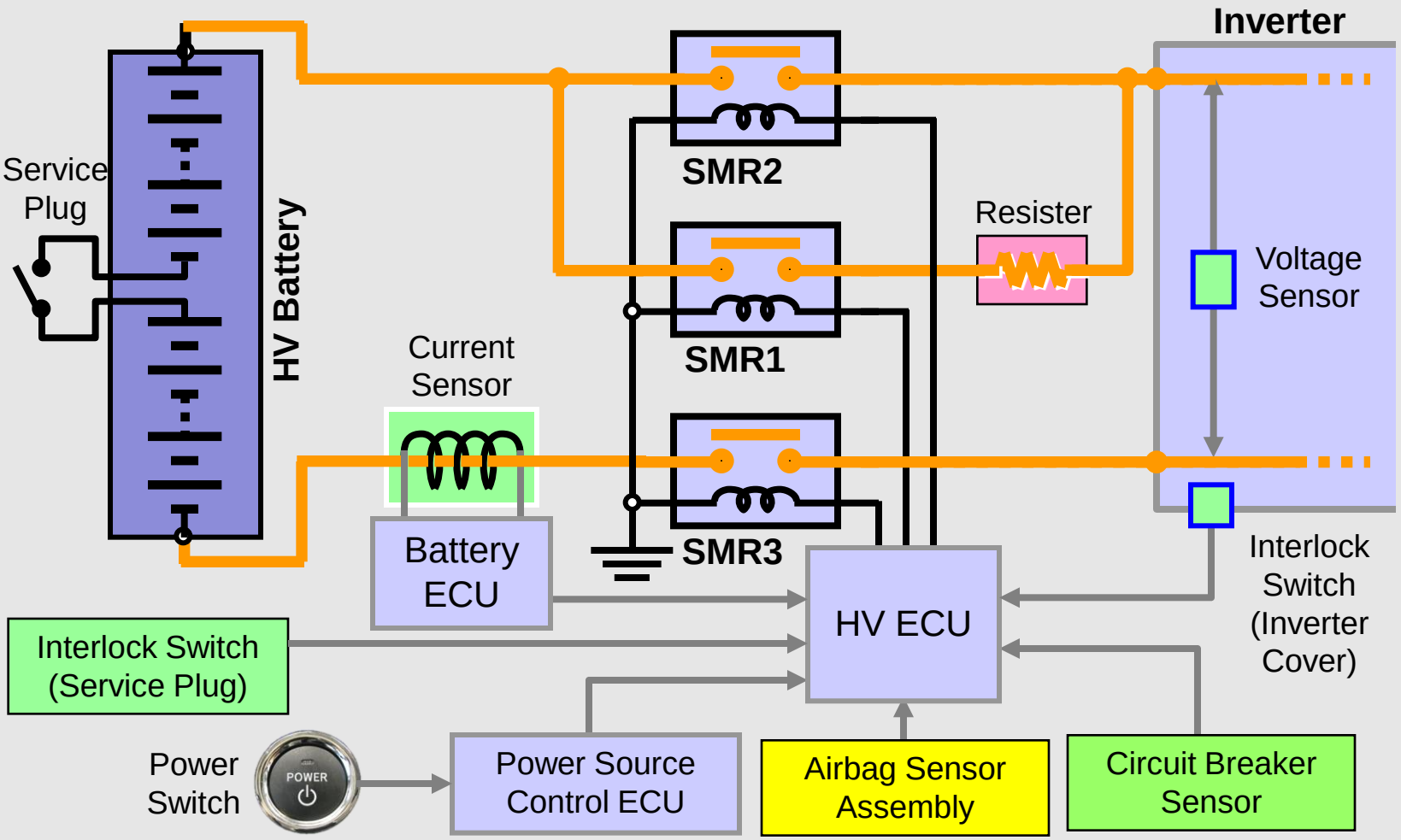
System Main relay



Notice: *Detection area and malfunction portion is different*

TOYOTA

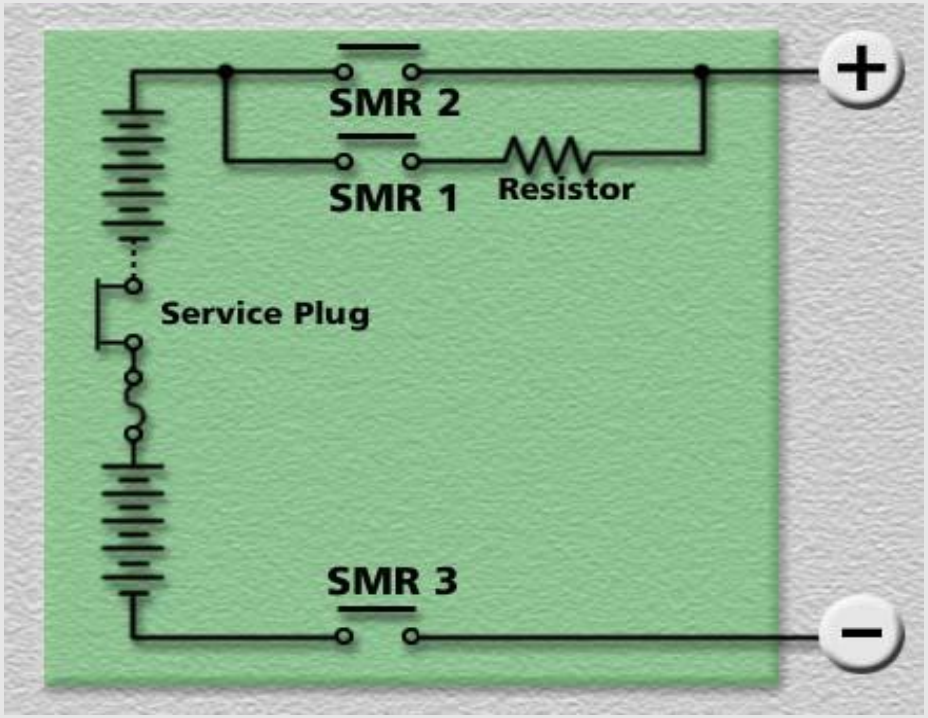
SMR (System Main Relay)



TOYOTA

HV Battery

- SMR (System Main Relay)
  - READY ON



STEP 1:
SMR 1 / SMR 3 → ON

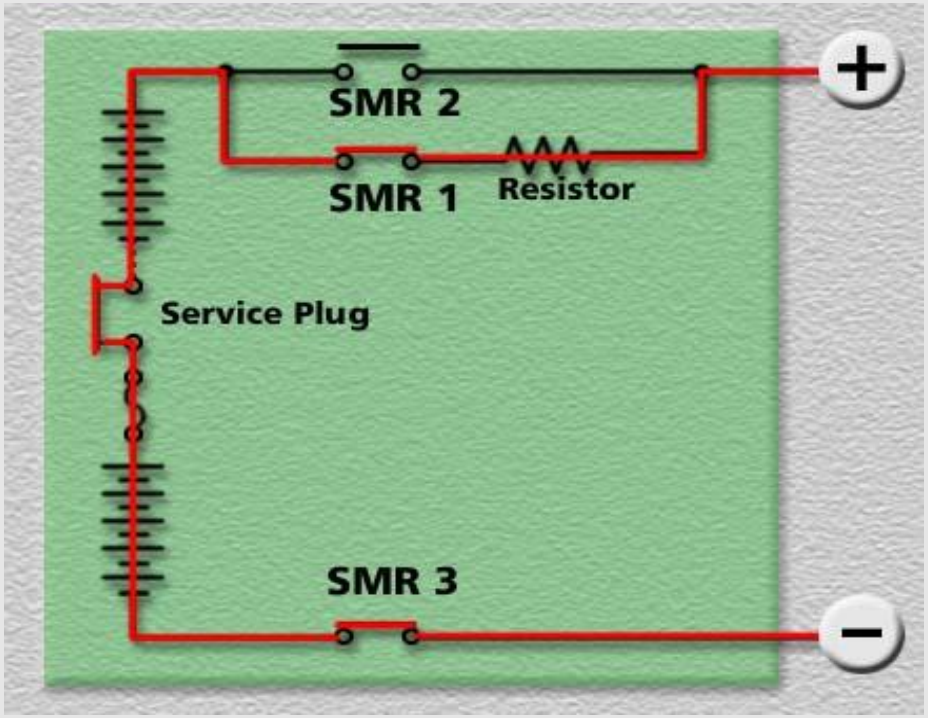
STEP 2:
SMR 2 → ON

STEP 3:
SMR 1 → OFF

TOYOTA

HV Battery

- SMR (System Main Relay)
  - READY ON



STEP 1:
SMR 1 / SMR 3 → ON

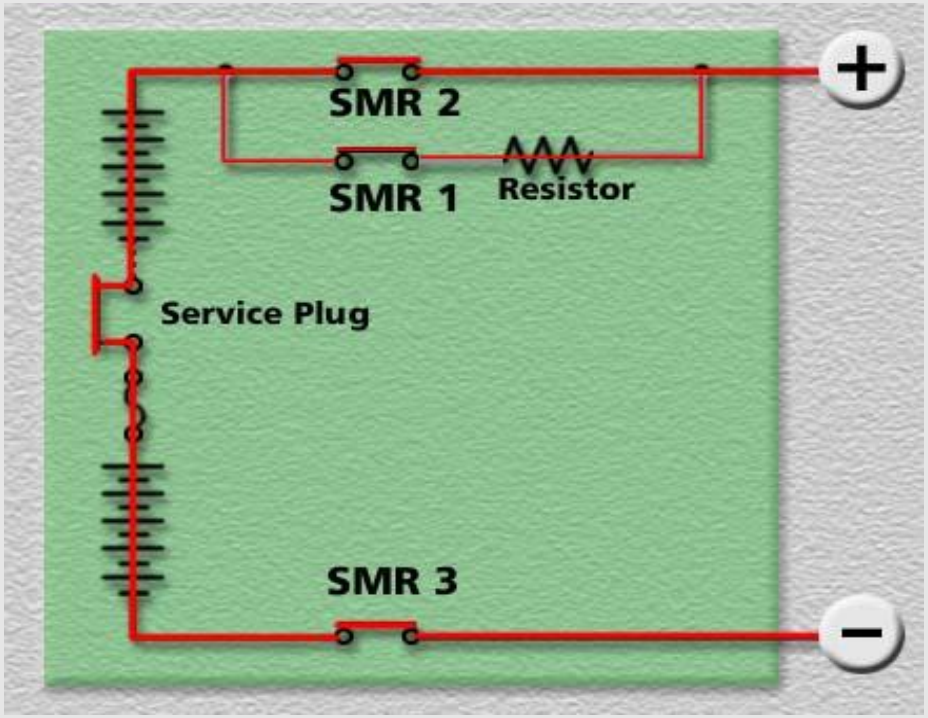
STEP 2:
SMR 2 → ON

STEP 3:
SMR 1 → OFF

TOYOTA

HV Battery

- SMR (System Main Relay)
  - READY ON



STEP 1:
SMR 1 / SMR 3 → ON

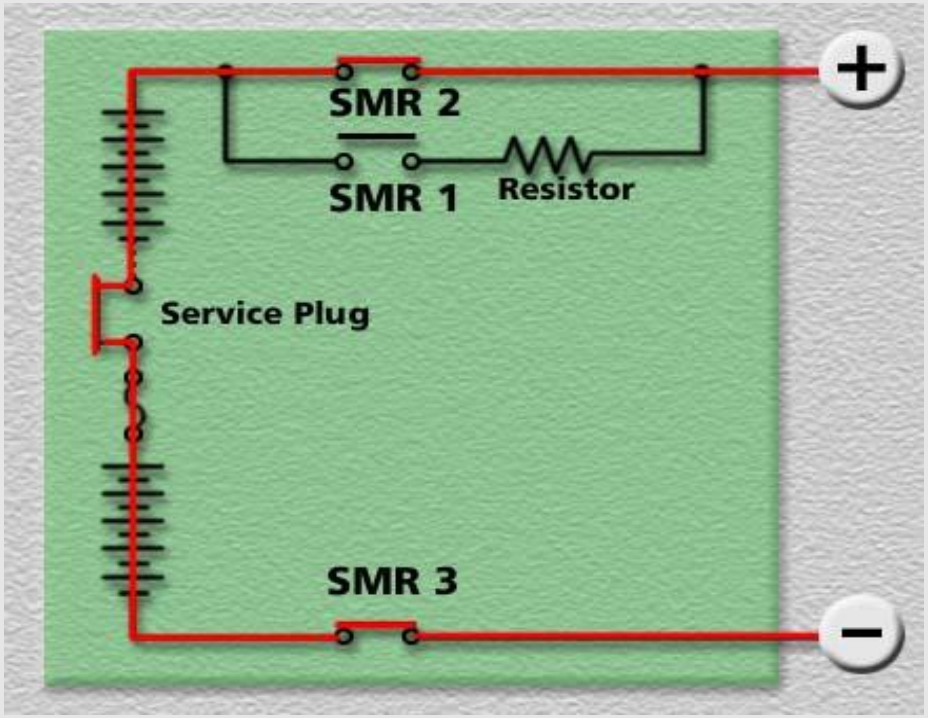
STEP 2:
SMR 2 → ON

STEP 3:
SMR 1 → OFF

TOYOTA

HV Battery

- SMR (System Main Relay)
  - READY ON



STEP 1:
SMR 1 / SMR 3 → ON

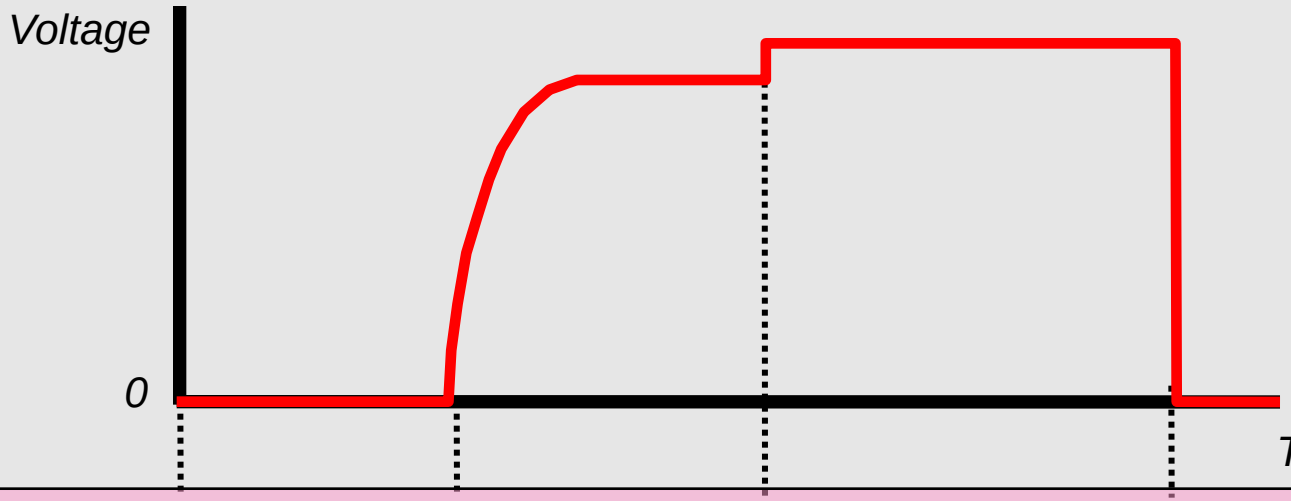
STEP 2:
SMR 2 → ON

STEP 3:
SMR 1 → OFF

TOYOTA

SMR

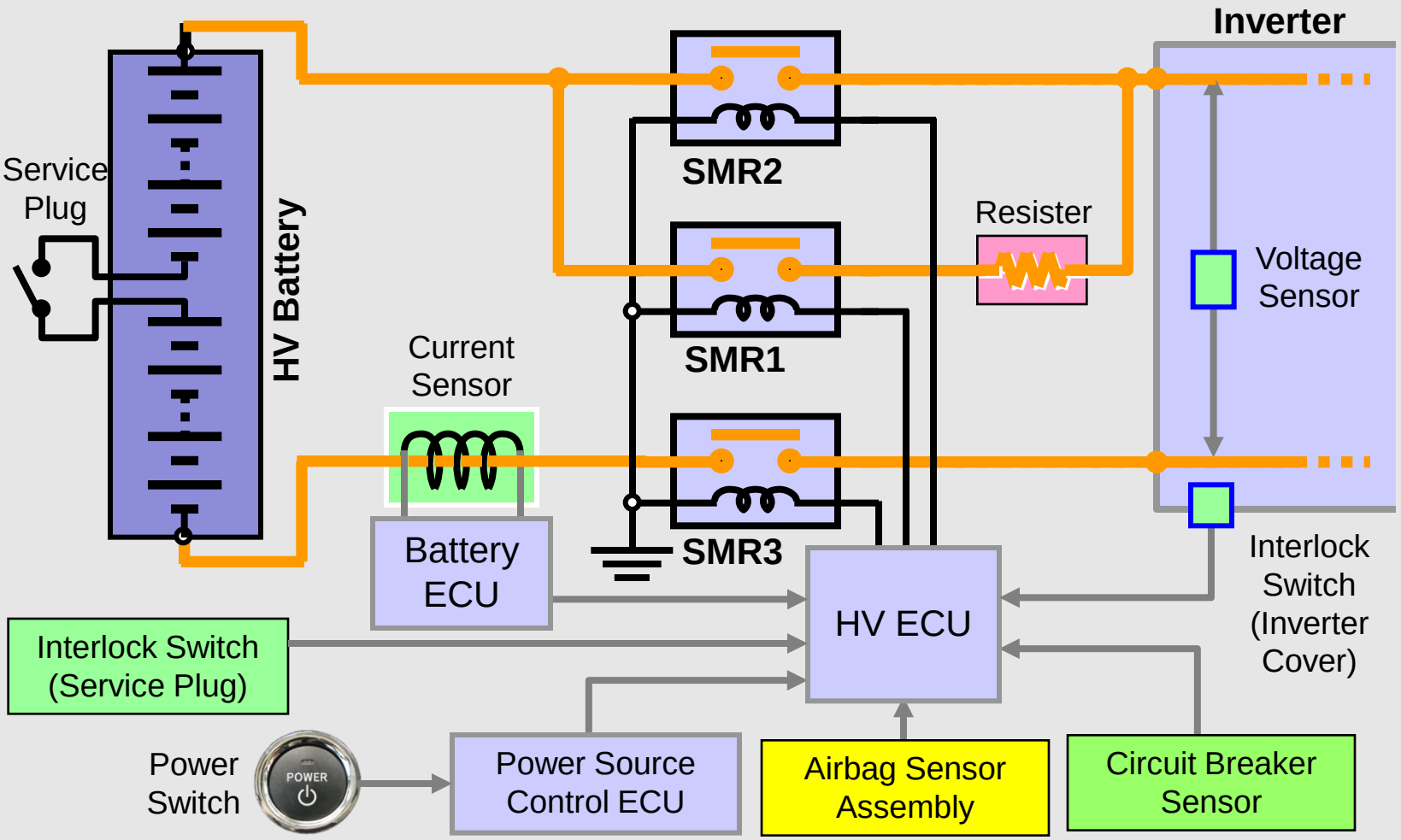
- Operation and System Voltage



(+)	SMR1	OFF	ON	OFF	OFF
	SMR2	OFF	OFF	ON	OFF
(-)	SMR3	OFF	ON	ON	OFF

TOYOTA

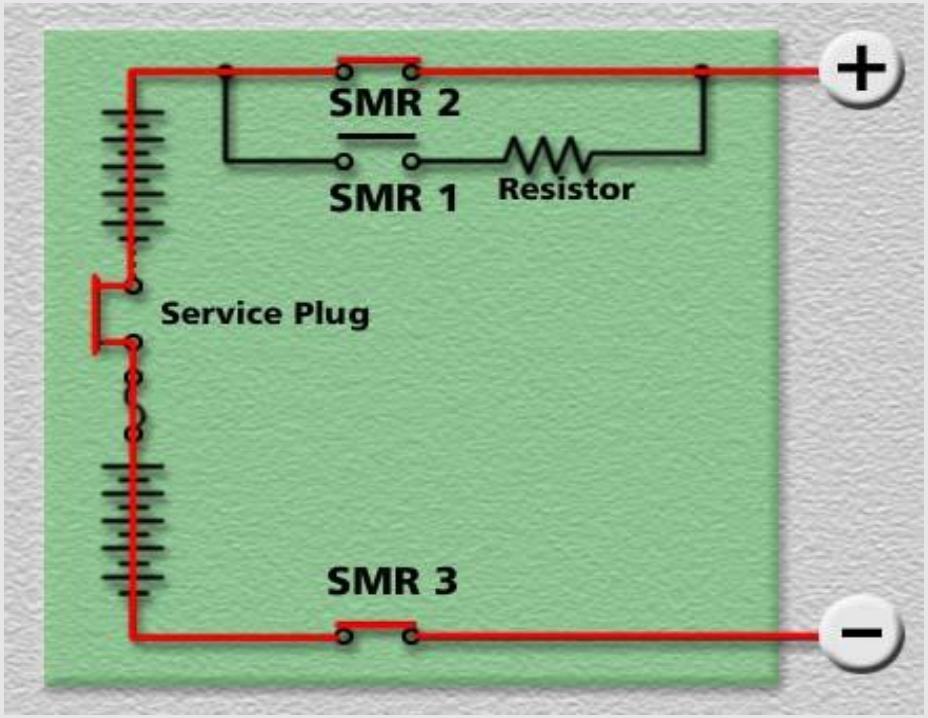
SMR (System Main Relay)



TOYOTA

HV Battery

- SMR (System Main Relay)
  - Power OFF



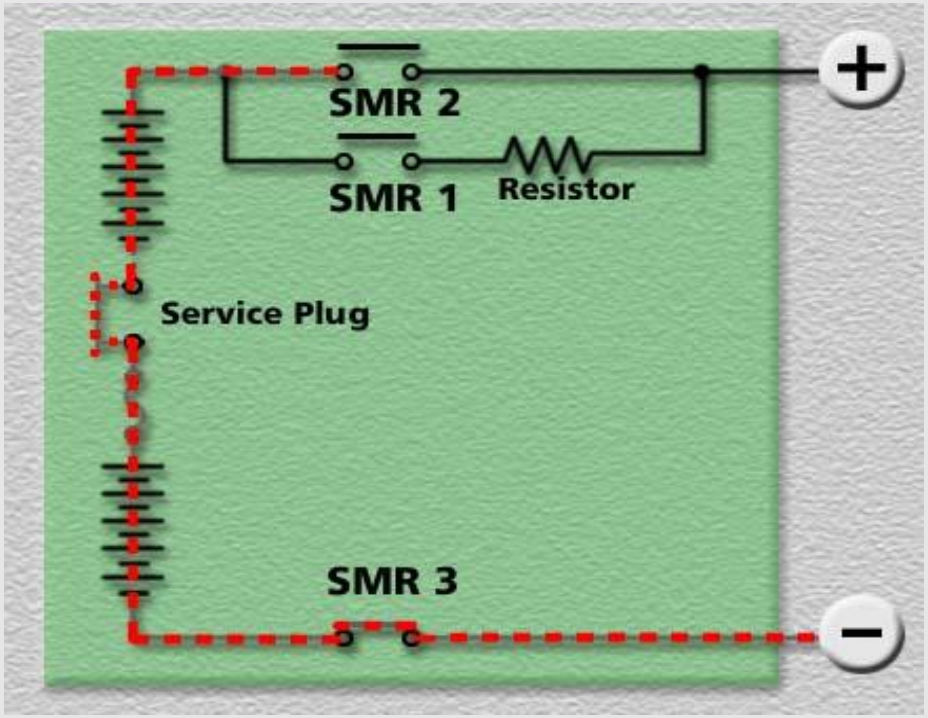
STEP 1:
SMR 2 → OFF

STEP 2:
SMR 3 → OFF

TOYOTA

HV Battery

- SMR (System Main Relay)
  - Power OFF



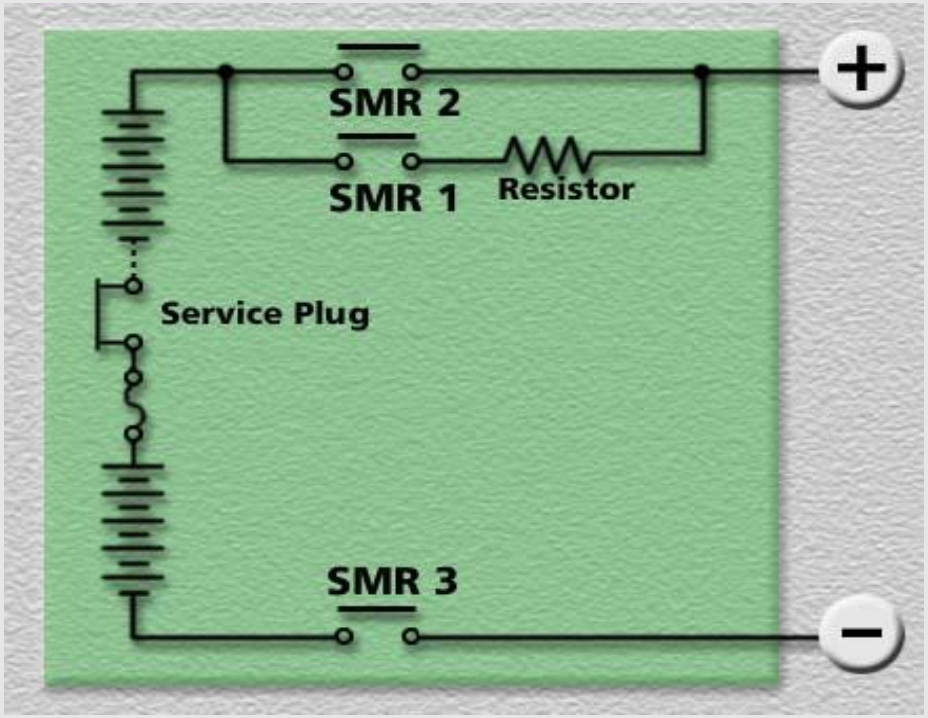
STEP 1:
SMR 2 → OFF

STEP 2:
SMR 3 → OFF

TOYOTA

HV Battery

- SMR (System Main Relay)
  - Power OFF



STEP 1:
SMR 2 → OFF

STEP 2:
SMR 3 → OFF

TOYOTA

SMR

- Diagnosis
  - Composition of SMR Diagnosis

1. HV ECU Internal Malfunction

2. Sensor or Actuator Malfunction
   – SMR Coil Open
   – Open or Short in Voltage Sensor Circuit
   – SMR Close Stuck

3. System Logical Deviation
   – High-voltage Wire Harness Malfunction

TOYOTA

SMR

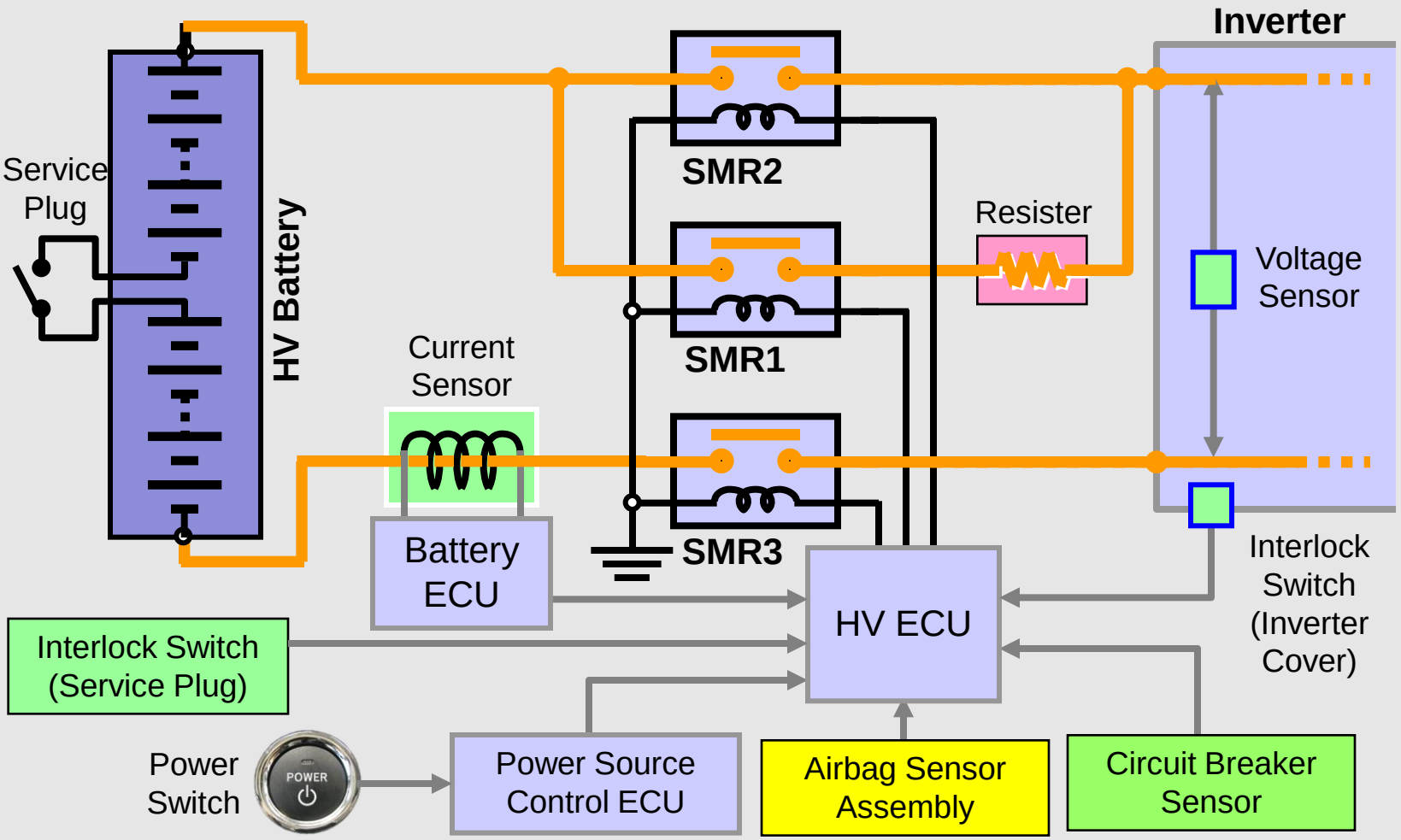
- Diagnosis
  - Sensor or Actuator Malfunction
    - › SMR Close Stuck

No.	Detection Item	Detection Method	
1	SMR2	SMR2 OFF → SMR3 OFF	
2	SMR3	SMR1 ON	Immediately after the IG/ON
3	SMR2 and SMR3	Discharging	
4	SMR1	SMR3 ON	

only for RX400h

TOYOTA

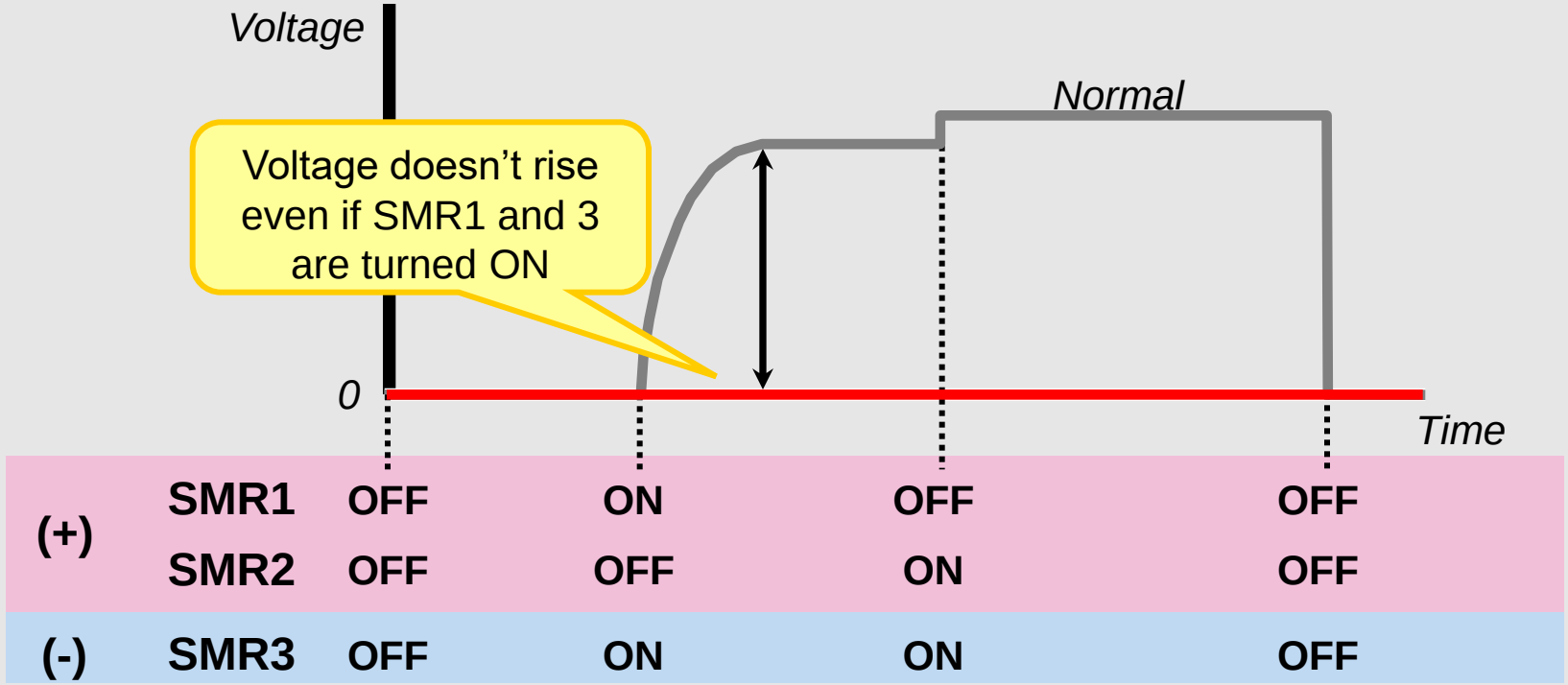
SMR (System Main Relay)



TOYOTA

SMR

- Diagnosis
  - System Logical Deviation
    - › High-voltage Wire Harness Malfunction



(+)	SMR1	OFF	ON	OFF	OFF
	SMR2	OFF	OFF	ON	OFF
(-)	SMR3	OFF	ON	ON	OFF

TOYOTA

Motor Control

- Diagnosis
  - Motor Control

1. HV ECU Internal Malfunction

2. Sensor or Actuator Malfunction
   – Resolver
   – Current Sensor
   – Temperature Sensor etc.

   } Open / Short Circuit, Range/Performance Problem

3. System Logical Deviation
   – Over-voltage, Over-current, Overheat
   – Gate Logical Deviation, MG1/2 System Malfunction, Motor Inverter Gate Malfunction, Monitoring MG1/2 Torque Performance, Magnetic Force Deterioration

TOYOTA

Motor Control

- Diagnosis
  - 3. System Logical Deviation

•<u>Over-voltage, Over-current, Overheat</u>

➢Monitors the sensor signal
(When DTC is detected, HV system is shutdown
→ it cannot drive)

•<u>Gate Logical Deviation</u>

➢The IGBT operation by the U.V.W signal is not correct

•<u>MG1/2 System Malfunction</u>

➢Actual current is different from the target current

Target Current: Calculated by the motor drive command (Transistor ON/OFF)

TOYOTA

Motor Control

- Diagnosis
  - 3. System Logical Deviation

- Motor Inverter Gate Malfunction
  (MG1: P0A7A-522 / MG2: P0A78-510)
  - ➢ There is still current after transmitting the shut down signal

- Monitoring MG1/2 Torque Performance
  (MG1: P0A7A-344 / MG2: P0A78-306)
  - ➢ Actual torque is different from the target torque

Actual Torque: Calculated from the current and speed/position of the motor

Target Torque: Calculated by the motor drive command (Transistor ON/OFF)

TOYOTA

Motor Control

- Diagnosis
  - 3. System Logical Deviation

Magnetic Force Deterioration

(MG1: P0A92-261)
(MG2: P0A90-251)

Features of Magnet

- It is weak against heat
- When magnetism decreases once, it doesn't revive by it self

TOYOTA

Motor Control

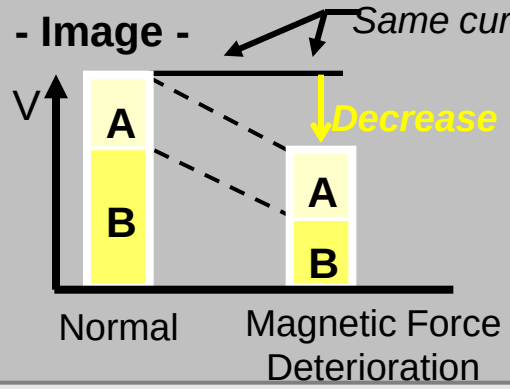
- Diagnosis
  - 3. System Logical Deviation

Detection of Magnetic Force Deterioration

1. To become a specified current value, the motor drive voltage is controlled
2. The voltage is monitored

Voltage decreases when magnetic force deterioration U=B x I x v

- Image -



A: Voltage needed to flow the specified current

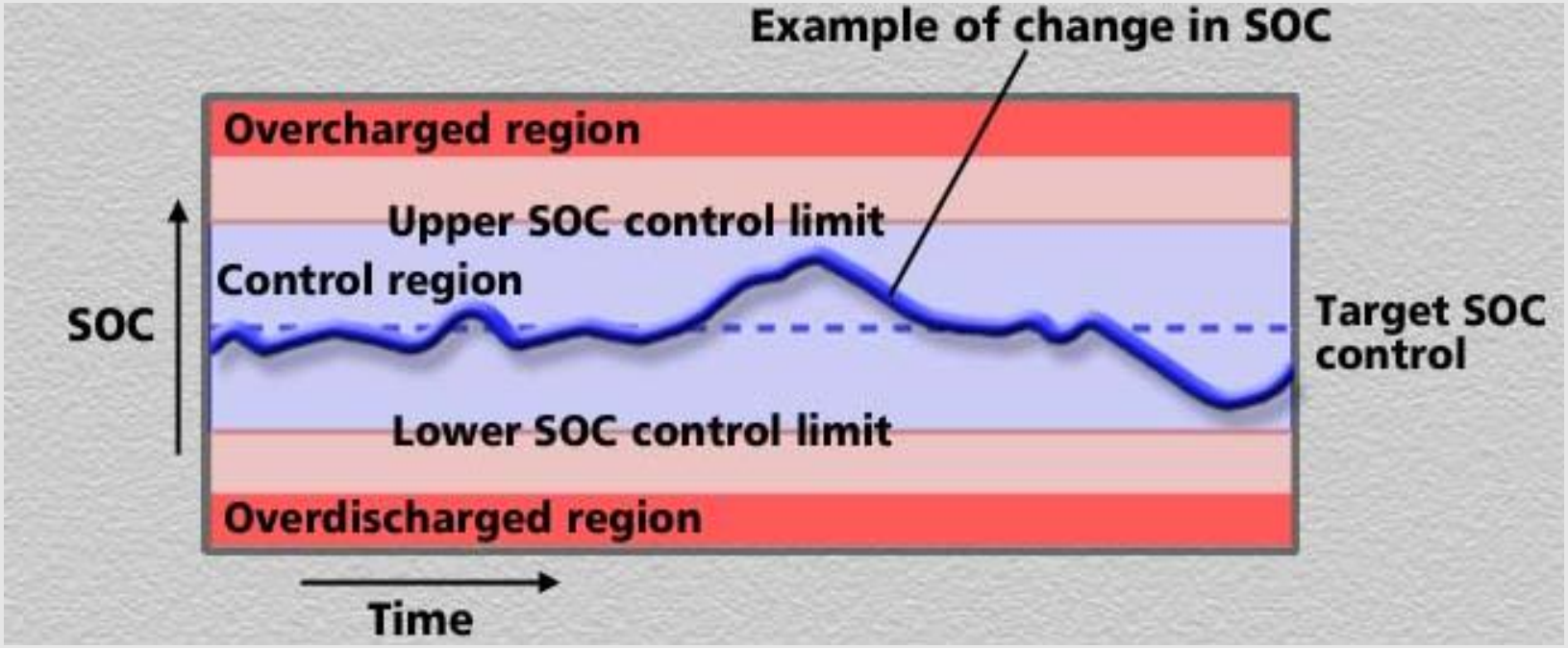
B: Voltage needed to rotate the rotor (magnet)

TOYOTA

HV Battery

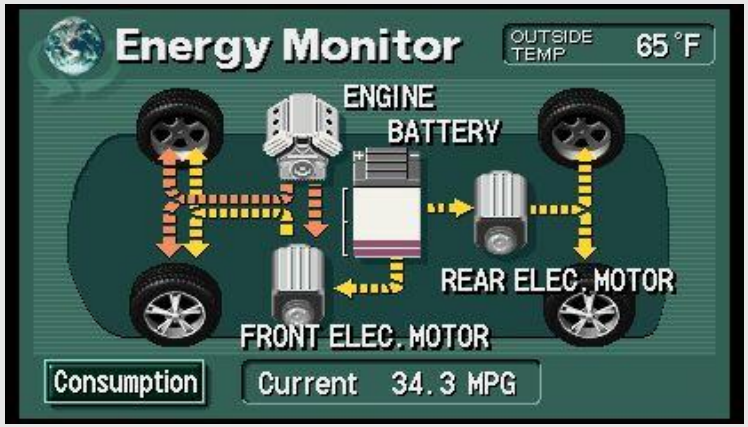
- What is the SOC ?

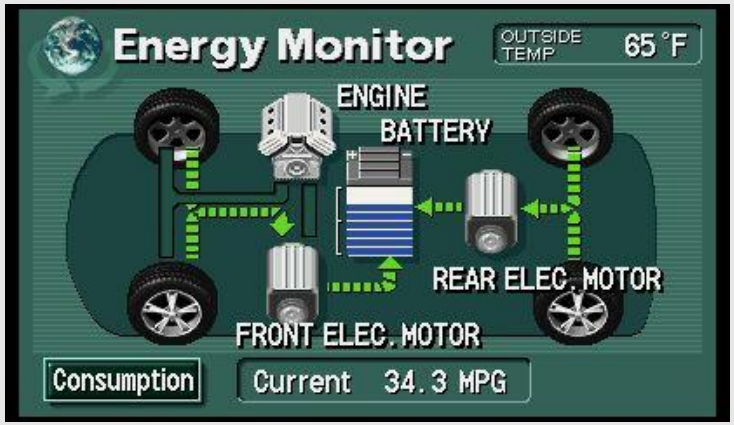
SOC (State of Charge) = Charging Rate



TOYOTA

HV Battery





SOC Indication

- SOC is indicated in 8 segments

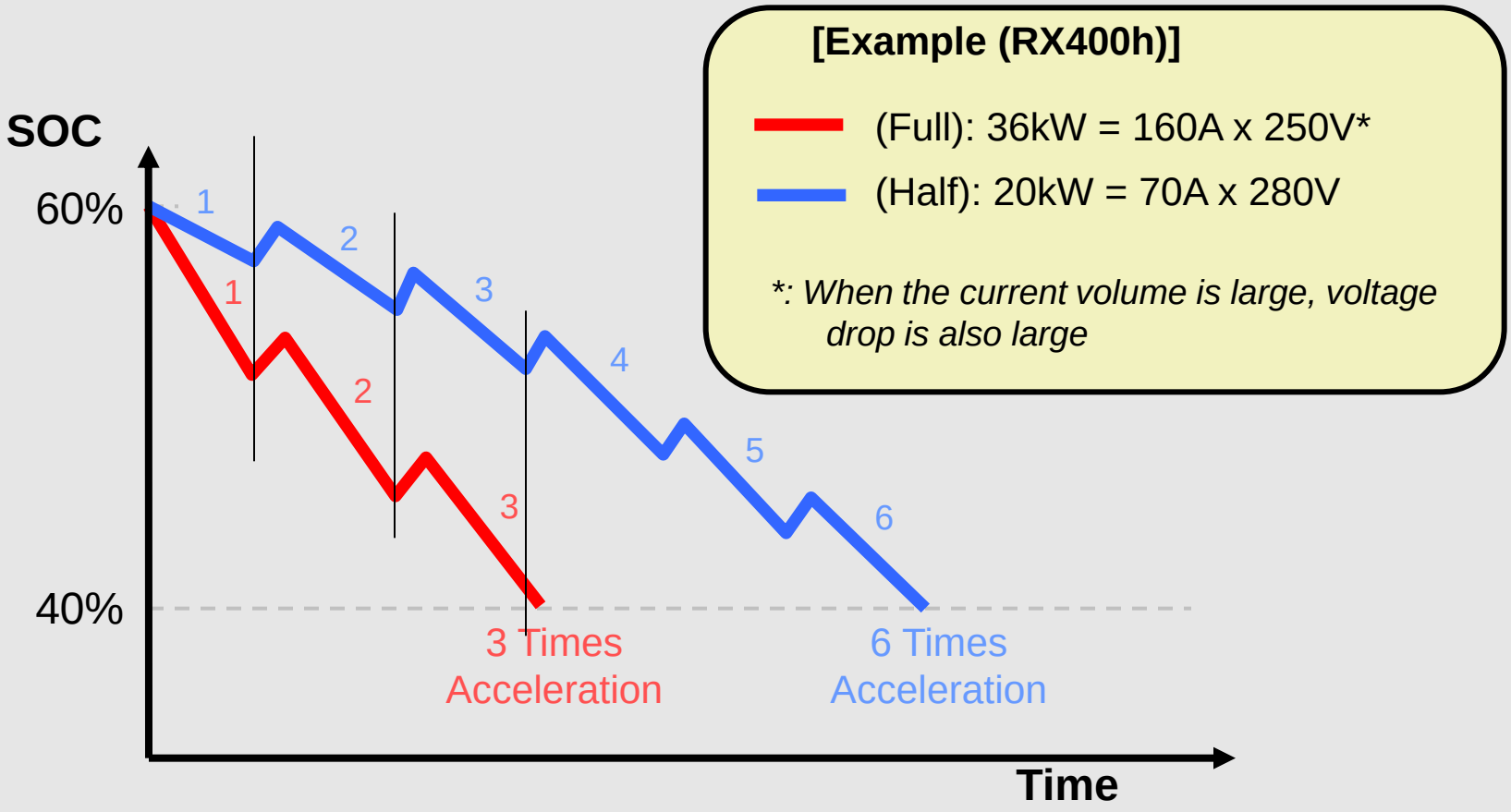
Color	Number of Segment
Green	7 ~ 8
Blue	3 ~ 6
Purple	1 ~ 2

- 8-segment ≠ SOC 100%
- 0-segment ≠ **SOC 0%**
- Power is determined by temperature (not by SOC)

TOYOTA

HV Battery

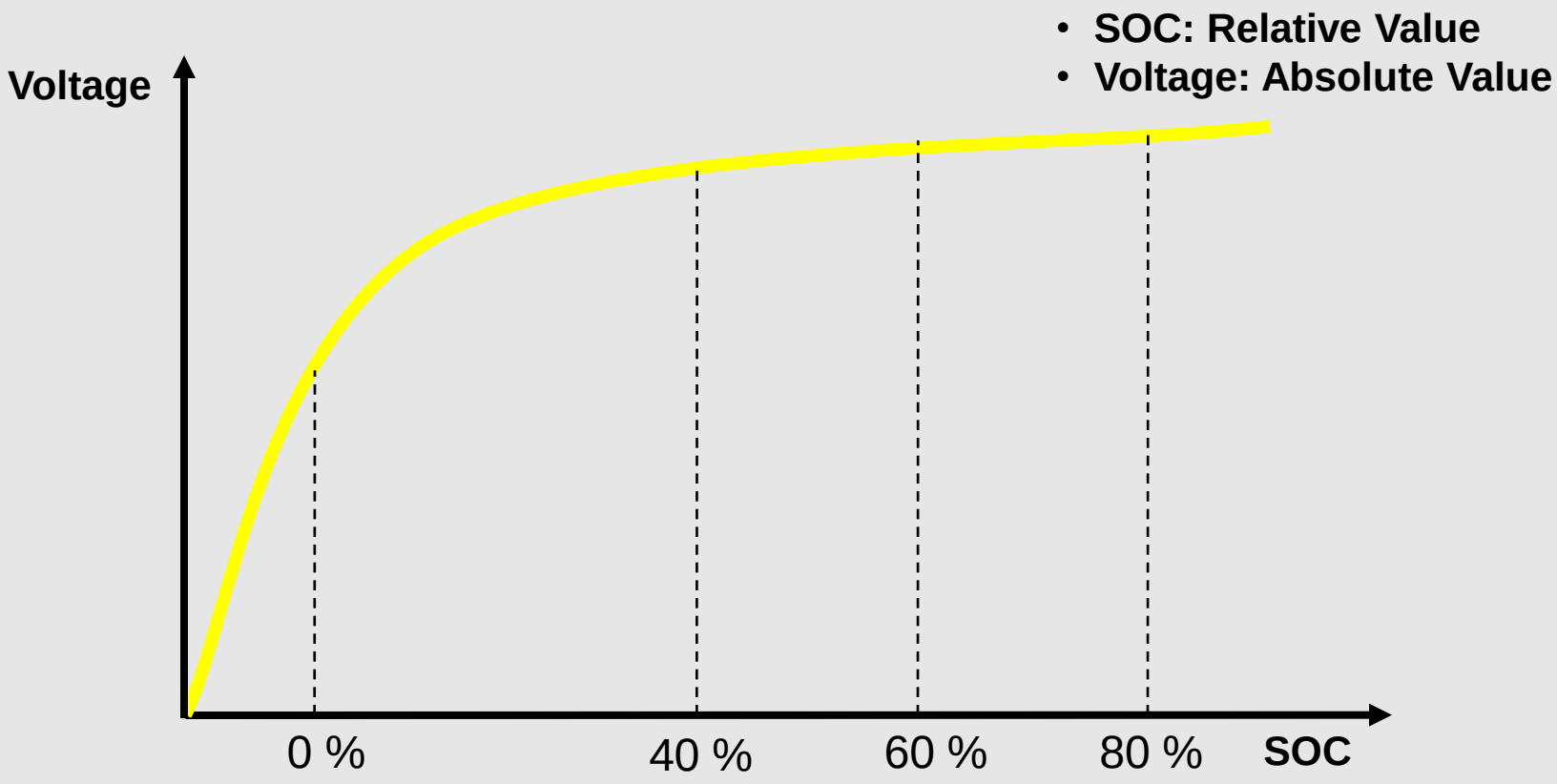
- SOC Calculation
  - SOC is calculated by current volume (IN / OUT)



TOYOTA

HV Battery

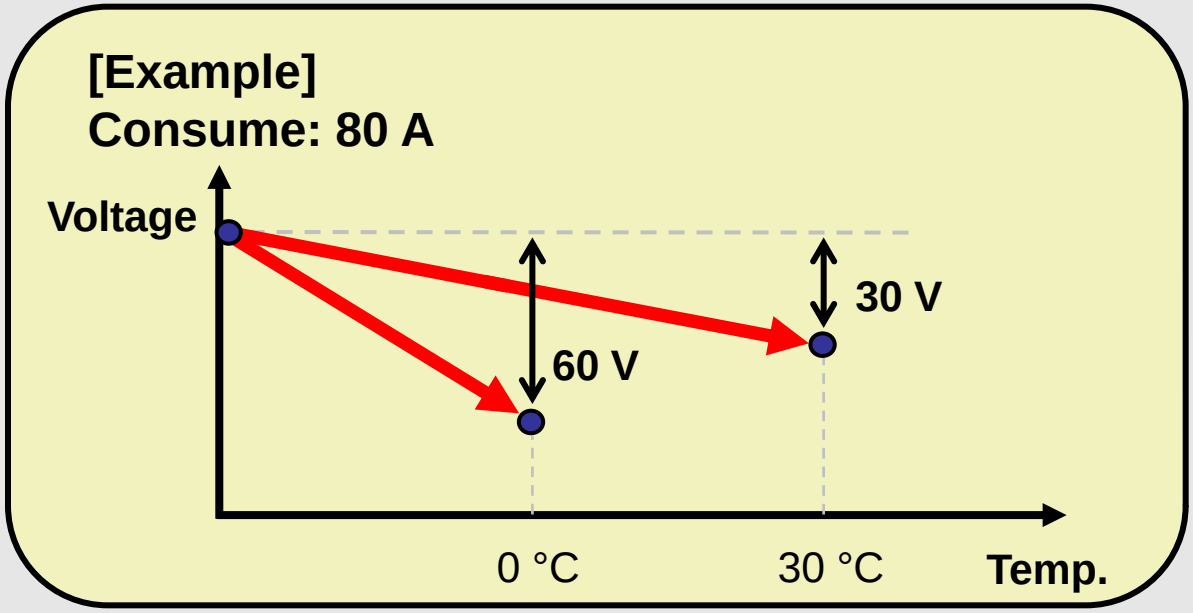
- SOC Calculation
  - SOC and Voltage



TOYOTA

HV Battery

- SOC Calculation
  - Voltage and Temperature



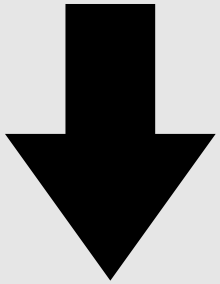
The voltage drop is different depending on the temperature, even if the SOC decrease is same

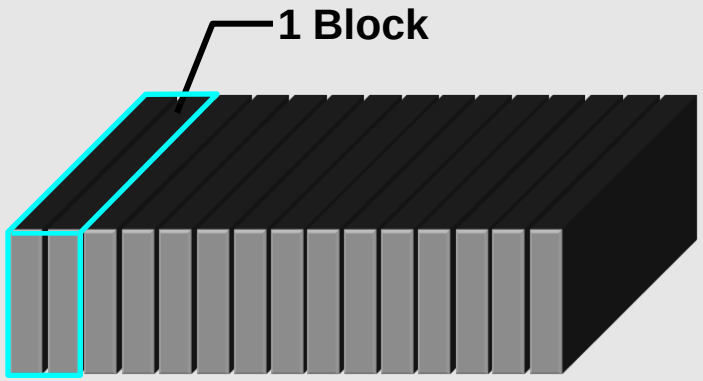
TOYOTA

HV Battery

- SOC Calculation

Monitors the SOC of each block





P0A7F: Battery pack deterioration

P0A80: Voltage difference

P3011 – P3025: Malfunction of each block

TOYOTA

HV Battery

- Diagnosis / Fail-safe (1) (RX400h)

<table>
<tr><th></th><th colspan="2">DTC No.</th><th colspan="2">Vehicle Condition</th><th>Failsafe</th></tr>
<tr><td rowspan="2">Battery ECU</td><td colspan="2" rowspan="2">P0A1F</td><td colspan="2">All Battery Monitoring becomes impossible</td><td>[Drive by engine] or [READY OFF]</td></tr>
<tr><td colspan="2">Some Battery Monitoring becomes impossible</td><td rowspan="4">Control level of some controls (SOC calculation, diagnosis) deteriorates</td><td rowspan="4">Limit the battery input/output</td></tr>
<tr><td>Voltage Sensor</td><td colspan="2">P3030</td><td>Voltage monitoring impossible</td></tr>
<tr><td>Current Sensor</td><td colspan="2">P0ABF
P0AC0
P0AC1
P0AC2</td><td>Current monitoring impossible</td></tr>
<tr><td>Tempe-rature Sensor</td><td>P0A9C
P0A9D
P0A9E
P0AC5
P0AC7</td><td>P0AC8
P0ACA
P0ACC
P0ACD</td><td>Temperature monitoring impossible</td></tr>
</table>

TOYOTA

HV Battery

- Diagnosis / Fail-safe (2) (RX400h)

	DTC No.		Vehicle Condition	Failsafe
Cooling System	P0A82 P0A84 P0A85 P0A97 P0A99	P0A9A P0AD0 P0AD2 P0AD3	By the inability of cooling performance, battery temperature rises	Limit the battery output
Battery	P0A7F		By the deterioration of battery performance, SOC decrease at discharge becomes fast	-
	P0A80		Battery cell malfunction	Limit the battery input/output
	P3011 – P3025		Battery cell malfunction	[Limit the battery input/output] or [Drive by engine] or [READY OFF]
Commu-nication	P3015		Battery monitoring inability	[Drive by engine] or [READY OFF]

TOYOTA

HV Battery

- Diagnosis / Fail-safe (3) (RX400h)

	DTC No.	Vehicle Condition	Failsafe
System	P0A95	High-voltage fuse blows	[Drive by engine] or [READY OFF]
	P0AF8	Voltage drop caused by malfunction in other system	READY OFF
	P3000-603	Temperature rises caused by malfunction in other system	[Drive by engine] or [READY OFF]
	P3000-388	SOC becomes very low (By the malfunction in other system, Vehicle is left in N range, Continues driving out of gas)	
	P3000-389	Voltage drops caused by malfunction in other system	READY OFF
	P3000-390	SOC becomes very high caused by the malfunction in other system	EV driving (Engine stop)
	P3004-133	Discharge current becomes over-current caused by malfunction in other system	READY OFF

TOYOTA

HV Battery

- Output Limit

Output Limit Conditions

1. High / Low Temperature
2. SOC is lower limit
3. Voltage is lower limit

4. Malfunction is detected

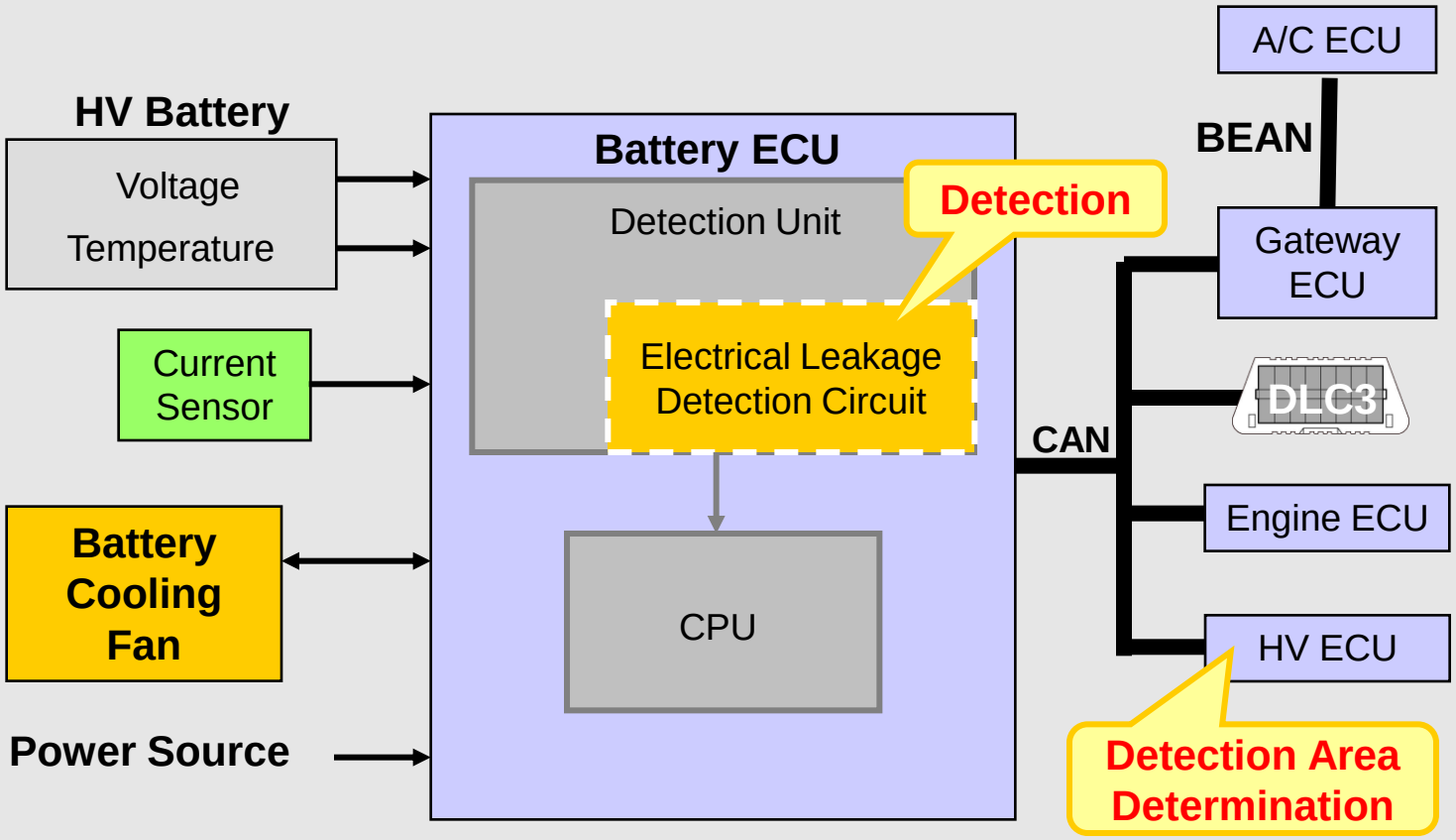
The output decrease of HV battery is covered by the engine output increase

There is almost no influence to the drivability

TOYOTA

Leakage Detection High Voltage Circuit

- System Diagram

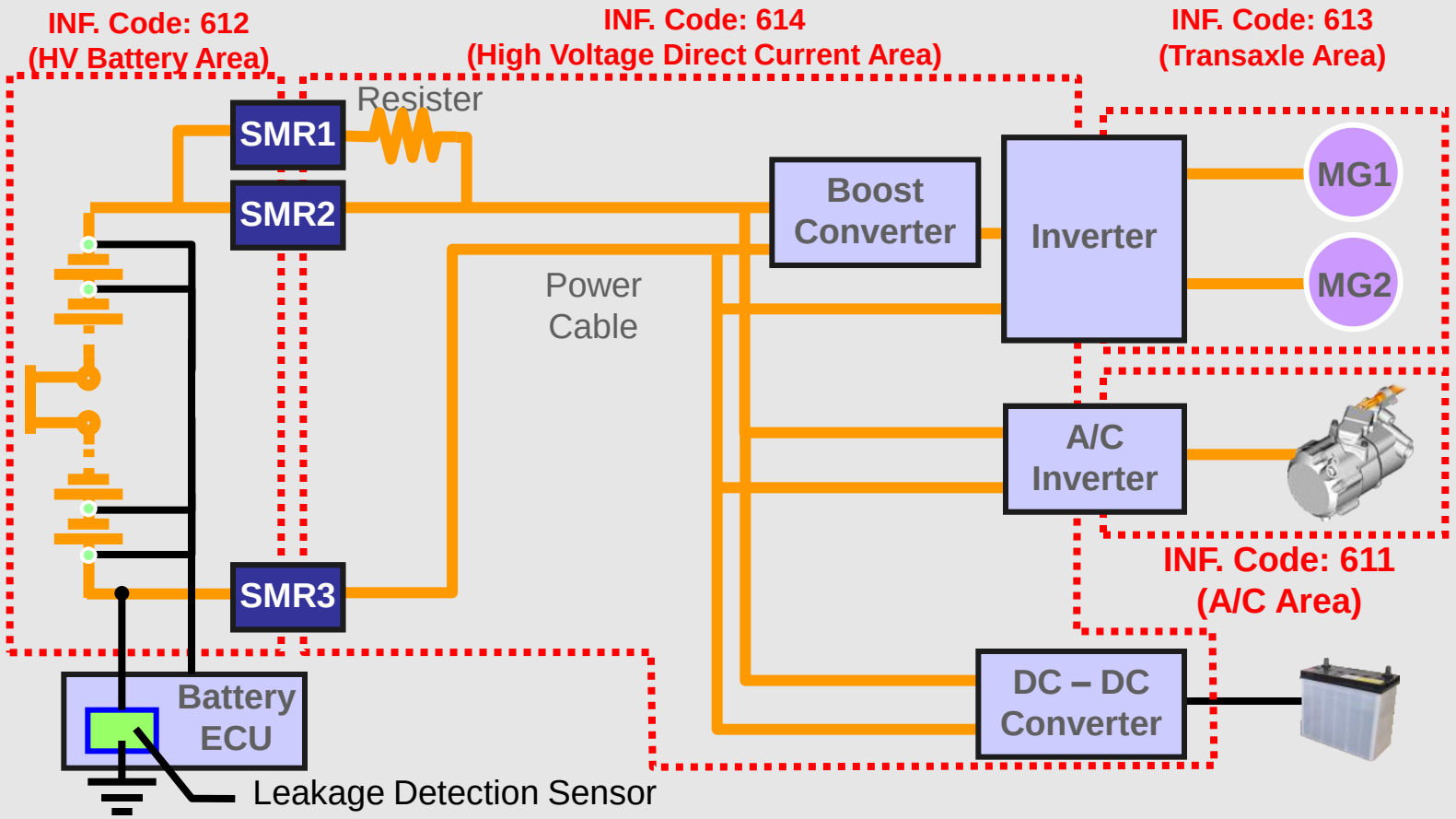


TOYOTA

Leakage Detection High Voltage Circuit

- Detection Area

Notice: Detection area and malfunction portion is different



TOYOTA

Leakage Detection High Voltage Circuit

- Diagnosis

1. Electrical leakage detection at high-voltage circuit
2. Automatic determination of detection area

Diagnosis Sequence

Step1: Electrical Leakage Detection -- [INF. Code 526]

Step2: A/C OFF (at driving) ---------- [INF. Code 611]

Step3: Power mode OFF (READY OFF)

Step4: Inverter (IGBT) OFF ---------- [INF. Code 613]

Step5: SMR OFF ---------- [INF. Code 612 or 614]

Don't turn OFF the power mode (10 sec.)

30 sec.

Point! It is necessary to wait for 30 sec. after power mode OFF to determine the detection area

TOYOTA

Leakage Detection High Voltage Circuit

- Detection Logic

Model	Insulation Resistance		
	Threshold Value	Standard Value	Standard Value on Repair Manual
PRIUS	120 kΩ	3.0 MΩ	2 – 10 MΩ (value is different according to the measurement point)
RX400h	150 kΩ	3.6 MΩ	

10 sec. x 3 times in 1 Trip

Total 30 sec.

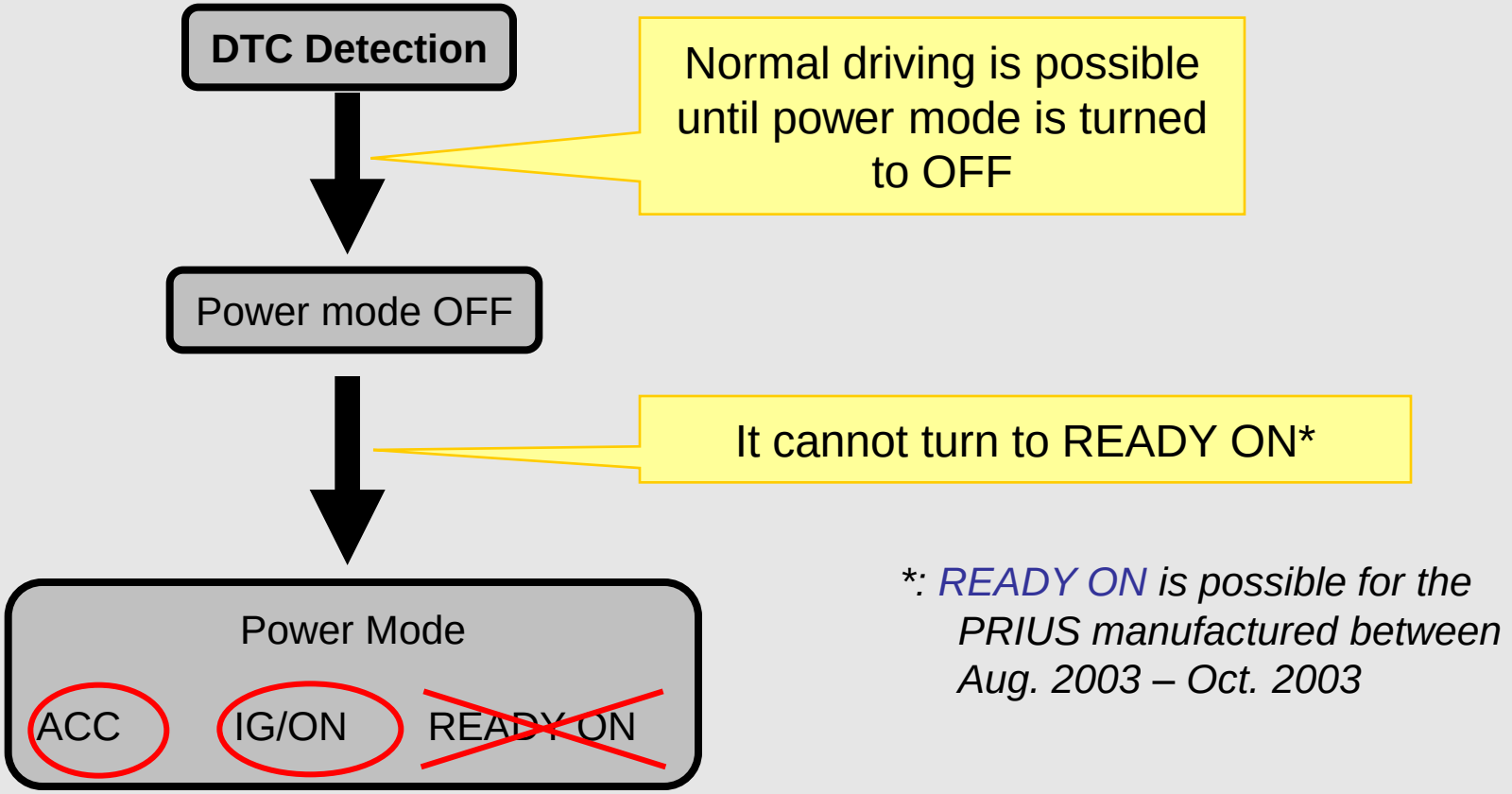
→ **Electrical Leakage Detection (INF. Code 526)**

Notice: Electrical leakage is not detected when the boost-up operation is performed

TOYOTA

Leakage Detection High Voltage Circuit

- Fail-safe



*: *READY ON is possible for the PRIUS manufactured between Aug. 2003 – Oct. 2003*

TOYOTA