Vehicle Certification Agency

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Decision Number: 2022/562664-VCA Issue: 0

Official Decision – Eco Innovation Approved

Legislation

Statutory Instruments 2019 no. 550, *The Road Vehicle Emission Performance Standards (Cars and Vans) (Amendment) (EU Exit) Regulations 2019.*
(In particular: Amendment of Commission Implementing Regulation (EU) No 725/2011 and 427/2014)

Details

Reason for Record: Application approved

Application Details

Applicant Name and Address:	ZF Friedrichshafen AG, Graf-von-Soden-Platz 1 88046 Friedrichshafen, GERMANY
Application Title/Description:	"48V Integrated Starter Generator (ISG) with efficient alternator function for use in hybrid powered passenger cars (M1) and light commercial vehicles (N1), including vehicles capable of running on alternative fuels"
Date submitted:	15/03/2022

Assessment Details

Assessment Number:	RDX562664
Date of Assessment Completion:	23/05/2022

Conclusion

The above-mentioned Application was assessed by the Vehicle Certification Agency in accordance with the above-mentioned legislation and was found to comply in all respects.

As of the date below, this Official Decision, and its Annexes, may allow manufacturers to benefit from a reduction of its average specific CO_2 emissions in Great Britain, by means of the CO_2 savings from the use of the innovative technology approved by this Official Decision. This shall be done in accordance with the above-mentioned legislation and shall reference this Decision in the application for a GB type-approval certificate for the vehicles concerned.

Signature:	 C McCABE Chief Technical and Statutory Operations Officer
Date:	23/05/2022
Assigned eco innovation code for GB:	32 (aligned to EU).

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Information regarding Certification of CO_2 Savings

1. A manufacturer may apply to VCA for certification of the CO_2 savings in Great Britain from the use of the innovative technology by reference to this Decision.

2. The manufacturer shall ensure that the application for the certification is accompanied by a verification report from an independent and certified body confirming that the technology conforms to the intended scope of the approved eco innovation and meets any relevant technical requirements as set out in the Annexes.

3. Where CO_2 savings have been certified by VCA, the manufacturer shall ensure that the certified CO_2 savings and the eco-innovation code are recorded in the certificate of conformity of the vehicles concerned (to be registered in Great Britain, only).

4. VCA shall ensure that CO_2 savings achieved from the use of the innovative technology have been determined using the methodology set out in the Annexes.

5. Where a manufacturer applies for the certification of the CO_2 savings for more than one type of this innovative technology in relation to one vehicle version, VCA shall determine which of those tested delivers the lowest CO_2 savings. That value shall be used for the purpose of paragraph 6.

6. VCA shall record the certified CO_2 savings calculated in accordance with the approved methodology (with the quantified uncertainty subtracted from the total savings to be certified) and the eco-innovation code referred to in this Decision in the relevant GB type-approval documentation.

7. In the case pre-defined CO_2 savings determined in accordance with Article 4(2)(ea) of Retained Implementing Regulation (EU) No 725/2011 and 427/2014, the relevant pre-defined savings value may be entered directly into the type approval documentation, provided that VCA is in a position to confirm that the vehicle is fitted with the technology in accordance with the specifications of this Decision.

8. VCA shall record all the elements considered for the certification in a test report and keep that together with the verification report referred to in paragraph 2.

9. VCA shall only certify CO_2 savings from the use of the innovative technology if it finds that the technology conforms with this Decision, and if the CO_2 savings determined in accordance with paragraph 6 are 0,5 g CO_2/km or higher, as specified in Article 9(1)(b) of Retained Implementing Regulation (EU) No 725/2011 in the case of passenger cars, or in Article 9(1)(b) of Retained Implementing Regulation (EU) No 427/2014 in the case of light commercial vehicles.

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Annexes

	Title	Number of pages
Annex I	SD_05 ZF Eco-Innovation ISG HEA Testing Methodology (REDACTED FOR CLARITY)	10

ANNEX I

Methodology to determine the CO2 savings of the ZF Friedrichshafen AG Highly efficient 48V Integrated Starter Generator (ISG) with efficient alternator function for use in hybrid powered passenger cars (M1) and light commercial vehicles (N1), including vehicles capable running on alternative fuels

1 INTRODUCTION

In order to determine the CO2 emission reductions that can be attributed to the use of the generation function of the ZF Friedrichshafen AG High efficient 48V motor generator (MG), hereinafter referred to as ISG, plus the 48V/12V-DC/DC converter, for use in hybrid powered vehicles it is necessary to specify the following:

(1) The test conditions;

(2) The test equipment;

(3) The procedure to determine the total efficiency;

(4) The procedure to determine the CO2 savings and the uncertainty of the CO2 savings.

(5) The procedure to determine the CO2 savings for certification.

The methodology in based on the Commission Implementing Decision (EU) 2020/1167.

2 SYMBOLS, PARAMETERS AND UNITS

Latin symbols

C_{CO2}	— CO2 savings in (g CO2/km)
CO2	— Carbon dioxide
CF	— Conversion factor as defined in **Table 3**
h	— Frequency as defined in **Table 1**
i	— Number of operating points
I	— Current intensity at which the measurement shall be carried out in (A)
I_R	— Rated current in (A)
l	— Number of measurements of the sample for the 48V/12V DC/DC converter
m	— Number of measurements of the sample for the 48V motor generator
M	— Torque in (Nm)
n	— Rotational frequency in (min− 1) as defined in **Table 1**
P	— Power in (W)

$s_{\overline{\eta_{DCDC}}}$ — Standard deviation of the 48V/12V DC/DC converter efficiency mean in (%)

$s_{\eta_{MG}}$ — Standard deviation of the 48V motor generator efficiency in (%)

$s_{\overline{\eta_{MG}}}$ — Standard deviation of the 48V motor generator efficiency mean in (%)

$s_{\eta_{TOT}}$ — Standard deviation of the total efficiency in (%)

$s_{C_{CO_2}}$ — Standard deviation of the total CO2 savings in (g CO2/km)

U — Test voltage at which the measurement shall be carried out in (V)

v — Mean driving speed of the Worldwide harmonized Light vehicles Test Cycle (WLTC) in (km/h)

VPe — Consumption of effective power in in (l/kWh) as defined in Table 2

Greek symbols

Δ — Difference

η_B — Baseline alternator efficiency in (%)

η_{DCDC} — 48V/12V DC/DC converter efficiency in (%)

$\overline{\eta_{DCDC}}$ — Mean of the 48V/12V DC/DC converter efficiency in (%)

η_{MG} — 48V motor generator efficiency in (%)

$\overline{\eta_{MG_i}}$ — Mean of the 48V motor generator efficiency at operating point i in (%)

η_{TOT} — Total efficiency in (%)

Subscripts

Index (i) refers to operating point

Index (j) refers to measurement of the sample

MG — Motor generator

m — Mechanical

RW — Real-world conditions

TA — Type approval (WLTP) conditions

B — Baseline

[redacted]

3 [redacted]

[redacted]

4 [redacted]

[redacted]

5 EFFICIENCY DETERMINATION

5.1 Efficiency of the 48V motor generator

The approach to determine the efficiency of the 48V motor generator is based on the ISO 8854:2012 methodology, with the following exceptions:

1. The rotational frequencies are adjusted for ISG systems with no additional ratio between the motor generator and the gearbox input shaft compared to a BSG system. The adjusted values are based on WLTC vehicle engine speed operation behaviour.
2. The frequency weighting each operating point also refer to a vehicle engine speed approach based on WLTC type approval conditions.

Evidence shall be provided to the type approval authority that the rotational frequency ranges of the efficient 48V motor generator are consistent with those set out in Table 1.

The measurements shall be conducted at different operating points, as set out in Table 1. The efficient 48V motor generator current intensity shall be defined as half of the rated current I_R for operating points 1 to 4. For each rotational frequency, the voltage and the output current of the motor generator shall be kept constant, the voltage at 52V.

Table 1

Operating points

Operating point i	Holding time [s]	Rotational frequency n_i [min– 1]	Motor generator current intensity I [A]	Frequency h_i
1	1200	950	I_R /2	0,30
2	1200	1250	I_R /2	0,50
3	600	1550	I_R /2	0,16
4	300	1850	I_R /2	0,04

The efficiency at each operating point shall be calculated in accordance with Formula 1:

Formula 1

$$\eta_{MG_i} = \frac{60 \cdot U_i \cdot I_i}{2\pi \cdot M_i \cdot n_i} \cdot 100$$

where, for each operating point i

U_i is the test voltage of 52 V

I_i is the current intensity as set out in *Table 1*

M_i is the measured torque

n_i is the rotational frequency as set out in *Table 1*

All efficiency measurements are to be performed consecutively at least five (5) times. The average of the measurements at each operating point $\overline{\eta_{MG_i}}$ shall be calculated.

The efficiency of the generation function η_{MG} shall be calculated in accordance with the following Formula 2:

Formula 2

$$\eta_{MG} = \sum_{i=1}^{4} h_i \cdot \overline{\eta_{MG_i}}$$

where

$\overline{\eta_{MG_i}}$ is the mean efficiency of the 48V motor-generator determined for operating point i (%)

h_i is the frequency of operating point i, as set out in **Table 1**.

5.2 Efficiency of the 48V/12V-DC/DC converter

The efficiency of the 48V/12V-DC/DC converter shall be determined under the following conditions:

– Input voltage of 52 V

– Output voltage of 14,3 V

– Output current of nominal power of the 48V/12V-DC/DC converter divided by 14,3 V

The nominal power of the 48V/12V-DC/DC converter shall be the continuous output power at the 12V side guaranteed by the manufacturer of the DC/DC converter at the conditions specified in the ISO 8854:2012.

The efficiency of the 48V/12V-DC/DC converter $\eta_{DC/DC}$ in (%) shall be calculated in accordance with Formula 3 with the results of the voltage and current intensity:

Formula 3

$$\eta_{DC/DC} = \frac{U_{12V} \cdot I_{12V}}{U_{48V} \cdot I_{48V}}$$

With:

U_{48V} is the input voltage, which shall be set to 52 (V)

I_{48V} is the current intensity measured on the input side (A)

U_{12V} is the output voltage, which shall be set to 14,3 (V)

I_{12V} is the current intensity measured on the output side, which should be equal to the nominal power of the 48V/12V DC/DC converter divided by the output voltage

The measured shall be carried out at least five (5) times consecutively.

The average of all the measurements is the efficiency of the 48V/12V-DC/DC converter $\overline{\eta_{DCDC}}$ in (%).

5.3 Total efficiency

The total efficiency of the 48 V motor generator plus the 48V/12V DC/DC converter shall be calculated using Formula 4:

Formula 4

$$\eta_{TOT} = \eta_{MG} \cdot \overline{\eta_{DCDC}}$$

where

η_{MG} is the efficiency of the 48V motor-generator, as determined in point 5.1 in (%)

$\overline{\eta_{DCDC}}$ is the efficiency of the 48V/12V DC/DC converter, as determined in point 5.2 in (%)

6 CALCULATION OF THE CO2-SAVINGS

6.1 Saved mechanical power

The 48 V motor generator plus the 48V/12V-DC/DC converter generation function lead to saved mechanical power under real-world conditions ΔP_{mRW} and type approval WLTC conditions ΔP_{mTA} as set out in Formula 5.

Formula 5

$$\Delta P_m = \Delta P_{mRW} - \Delta P_{mTA}$$

Where the saved mechanical power under real-world conditions ΔP_{mRW} shall be calculated in accordance with Formula 6 and the saved mechanical power under type-approval WLTC conditions ΔP_{mTA} in accordance with Formula 7:

Formula 6

$$\Delta P_{mRW} = \frac{P_{RW}}{\eta_B} - \frac{P_{RW}}{\eta_{TOT}}$$

Formula 7

$$\Delta P_{mTA} = \frac{P_{TA}}{\eta_B} - \frac{P_{TA}}{\eta_{TOT}}$$

where

η_{TOT} is the efficiency of the 48V motor-generator combined with the 48V/12V DC/DC converter, as determined in point 5.3 in (%)

P_{RW} is the power requirement under 'real-world' conditions, which is 750 W

P_{TA} is the power requirement under 'type-approval' conditions, which is 350 W

η_B is the efficiency of the baseline alternator, which is 67 %

6.2 Calculation of the CO_2 savings

The CO2 savings of the 48 V motor generator plus the 48V/12V-DC/DC converter shall be calculated in accordance with Formula 8:

Formula 8

$$C_{CO2} = \Delta P_m \cdot \frac{V_{Pe} \cdot CF}{v}$$

where

ΔP_m is the difference between the saved mechanical power under real-world conditions and the saved mechanical power under type-approval conditions, as determined in point 6.1

v is the mean driving speed of the WLTC, which is 46,6 km/h

VPe is the consumption of effective power specified in Table 2:

CF is the conversion factor (l/100 km) - (g CO2/km) [gCO2/l] as defined in Table 3

Table 2

Consumption of effective power

Type of engine	Consumption of effective power (VPe) in (l/kWh)
Petrol- or E85-fueeld other than turbo-charged	*0,264*
Turbo-charged petrol- or E85 fuelled	*0,280*
Diesel-fuelled	*0,220*
LPG-fuelled	*0,342*
Turbo-charged LPG-fuelled	*0,363*
	Consumption of effective power (VPe) in (m^3/kWh)
CNG (G20) other than turbo-charged	*0,259*
Turbo-charged CNG (G20)	*0,275*

Table 3

Fuel conversion factor

Type of fuel	Conversion factor in (gCO2/l)
Petrol/E85	*2 330*
Diesel	*2 640*
LPG	*1 629*
	Conversion factor in (gCO2/m³)
CNG (G20)	*1 795*

Table 2 and Table 3 are in accordance with CID (EU) 2020/1232 including the latest values also for alternative fuels.

6.3 Calculation of the statistical margin

The statistical margin of the results of the testing methodology caused by the measurements shall be quantified. For each operating point the standard deviation shall be calculated in accordance with Formula 9:

Formula 9

$$s_{\overline{\eta_{MG_i}}} = \frac{s_{\eta_{NG_i}}}{\sqrt{m}} = \sqrt{\frac{\sum_{j=1}^{m}(\eta_{MG_{i_j}} - \overline{\eta_{MG_i}})^2}{m(m-1)}}$$

where

m is the number of measurements j undertaken at each operating point i for the 48V motor-generator efficiency, as referred to in point 5.1

$\eta_{MG_{i_j}}$ is the efficiency of the 48V motor-generator calculated for an individual measurement j at operating point i as referred to in point 5.1 in (%)

$\overline{\eta_{MG_i}}$ is the average efficiency of the 48V motor-generator calculated for an operating point i, as determined in point 5.1 in (%)

The standard deviation of the efficiency value of the efficient 48V motor generator ($s_{\eta_{MG}}$) shall be calculated in accordance with Formula 10:

Formula 10

$$s_{\eta_{MG}} = \sqrt{\sum_{i=1}^{4}\left(h_i \cdot s_{\overline{\eta_{MG_i}}}\right)^2}$$

where

$s_{\overline{\eta_{MG_i}}}$ is as determined by Formula 9

h_i is the frequency of operating point i, as set out in Table 1.

The standard deviation of the efficiency value of the 48V/12V-DC/DC converter $s_{\overline{\eta_{DCDC}}}$ shall be calculated in accordance with Formula 11:

Formula 11

$$s_{\overline{\eta_{DCDC}}} = \sqrt{\frac{\sum_{j=1}^{l}(\eta_{DCDC_l} - \overline{\eta_{DCDC}})^2}{l(l-1)}}$$

where

l is the number of measurements l undertaken for the 48V/12V DC/DC converter, as referred to in point 5.2

η_{DCDC_l} is the efficiency of the 48V/12V DC/DC converter calculated for an individual measurement l as referred to in point 5.2 in (%)

$\overline{\eta_{DCDC}}$ is the efficiency of the 48V/12V DC/DC converter, as determined in point 5.2 in (%)

The standard deviation of the motor generator efficiency $s_{\eta_{MG}}$ and of the 48V/12V-DC/DC converter $s_{\overline{\eta_{DCDC}}}$ lead to an uncertainty in the CO2 savings $s_{C_{CO2}}$. That uncertainty is calculated in accordance with Formula 12:

Formula 12

$$s_{C_{CO_2}} = \frac{(P_{RW} - P_{TA})}{\eta_{TOT}} \cdot \frac{V_{Pe} \cdot CF}{v} \cdot \sqrt{\left(\frac{s_{\eta_{MG}}}{\eta_{MG}}\right)^2 + \left(\frac{s_{\overline{\eta_{DCDC}}}}{\overline{\eta_{DCDC}}}\right)^2}$$

where

P_{RW} is the power requirement under 'real-world' conditions, which is 750 W

P_{TA} is the power requirement under type-approval conditions, which is 350 W

η_{TOT} is the total efficiency of the 48V motor-generator combined with the 48V/12V DC/DC converter as determined in point 5.3 in (%)

V_{Pe} is the consumption of effective power as specified in Table 2

CF is the fuel conversion factor as specified in Table 3

v is the mean driving speed of the WLTP, which is 46,6 km/h

$s_{\eta MG}$ is standard deviation of the efficiency of the 48V motor-generator as determined in accordance with Formula 10 in (%)

η_{MG} is the efficiency of the 48V motor-generator, as determined in point 5.1 in (%)

$s_{\overline{\eta DCDC}}$ is the standard deviation of the efficiency of the 48V/12V DC/DC converter, as determined in accordance with Formula 11 in (%)

$\overline{\eta_{DCDC}}$ is the efficiency of the 48V/12V DC/DC converter as determined in point 5.2 in (%)

6.4 Rounding

The calculated CO2 savings value (CCO2) and the statistical margin of the CO2 saving ($s_{C_{CO2}}$) must be rounded to a maximum of two decimal places.

Each value used in the calculation of the CO2 savings can be applied unrounded or must be rounded to the minimum number of decimal places which allows the maximum total impact (i.e. combined impact of all rounded values) on the savings to be lower than 0,25 gCO2/km.

6.5 Check against the minimum CO2 saving threshold

It shall be demonstrated for each type, variant and version of a vehicle fitted with the efficient 48V motor generator that the uncertainty of the CO2 savings calculated in accordance with Formula 7 is not greater than the difference between the total CO2 savings and the minimum savings threshold specified in Article 9(1) of Implementing Regulation (EU) No 725/2011 and Commission Implementing Regulation (EU) No 427/2014 ([1]) (see Formula 13).

Formula 13

$$(C_{CO2} - s_{C_{CO2}} - \Delta CO2_m) \geq MT$$

where

MT: is 0,5 g CO2/km as specified in Article 9(1)(b) of Implementing Regulation (EU) No 725/2011 and Commission Implementing Regulation (EU) No 427/2014

C_{CO2}: total CO2 saving in (g CO2/km) as determined in point 6.2

$s_{C_{CO2}}$: uncertainty of the total CO2 saving in(gCO2/km) as determined in point 6.3

$\Delta CO2_m$: CO2 correction coefficient due to the positive mass difference between the efficient 48V motor generator plus 48V/12V DC-DC converter and the baseline alternator. For ΔCO2m the data in Table 4 is to be used.

[1] Commission Implementing Regulation (EU) No 427/2014 of 25 April 2014 establishing a procedure for the approval and certification of innovative technologies for reducing CO_2 emissions from light commercial vehicles pursuant to Regulation (EU) No 510/2011 of the European Parliament and of the Council (OJ L 125, 26.4.2014, p. 57).

Table 4

CO2 correction coefficient due to the extra mass

Type of fuel	CO2 correction coefficient due to the positive mass difference ($\Delta CO2_m$) in (g CO2/km)
Petrol/E85	0,0277 * Δm
Diesel	0,0383 * Δm
LPG	0,0251 * Δm
CNG	0,0209 * Δm

In Table 4 Δ*m* is the extra mass due to the installation of the 48V motor generator and the 48V/12V-DC/DC converter. It is the positive difference between the mass of the 48V motor generator plus the 48V/12V-DC/DC converter and the mass of baseline alternator. The mass of the baseline alternator is 7 kg. The extra mass is to be verified and confirmed in the verification report to be submitted to the type approval authority together with the application for certifications.

7 CO2-SAVINGS CERTIFICATION

The CO2 savings to be certified by the type-approval authority in accordance with Article 11 of Implementing Regulations (EU) No 725/2011 or (EU) No 427/2014 CS_{CO_2} are those calculated in accordance with Formula 14.The CO2 savings shall be recorded in the type approval certificate for each vehicle version fitted with the 48V motor generator combined with the 48V/12V DC/DC converter.

Formula 14

$$CS_{CO_2} = (C_{CO_2} - s_{C_{CO_2}})$$

where

C_{CO_2} is the CO2 savings as determined in accordance with Formula 8 under point 6.2 in (g CO_2/km)

$s_{C_{CO_2}}$ is the uncertainty in the CO2 savings of the 48V motor-generator combined with the 48V/12V DC/DC converter calculated in accordance with Formula 12 under point 6.3 in (g CO_2/km)