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**Datasheet for the decision  
of 11 February 2019**

**Case Number:** T 2368/13 - 3.5.02

**Application Number:** 02028524.3

**Publication Number:** 1322028

**IPC:** H02M3/00

**Language of the proceedings:** EN

**Title of invention:**

Voltage conversion system and method and recording medium

**Applicant:**

TOYOTA JIDOSHA KABUSHIKI KAISHA

**Relevant legal provisions:**

EPC Art. 82, 84, 56

**Keyword:**

Unity of invention - main request (no) - aux. requests (yes)  
Claims - all essential features - main request & aux. requests  
1 to 3 (no) - aux. request 4 (yes)  
Clarity - main request & aux. requests 1 & 2 (no) - aux.  
requests 3 & 4 (yes)  
Inventive step - auxiliary request 4 (yes)



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Case Number: T 2368/13 - 3.5.02

**D E C I S I O N**  
**of Technical Board of Appeal 3.5.02**  
**of 11 February 2019**

**Appellant:** TOYOTA JIDOSHA KABUSHIKI KAISHA  
(Applicant) 1, Toyota-cho,  
Toyota-shi, Aichi-ken, 471-8571 (JP)

**Representative:** TBK  
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**Decision under appeal:** Decision of the Examining Division of the  
European Patent Office posted on 4 July 2013  
refusing European patent application No.  
02028524.3 pursuant to Article 97(2) EPC.

**Composition of the Board:**

**Chairman** R. Lord  
**Members:** G. Flynn  
R. Cramer

## Summary of Facts and Submissions

I. The applicant's appeal contests the examining division's decision to refuse the European patent application 02 028 524.3, which was published as EP 1 322 028 A2.

II. In the contested decision, the examining division considered the applicant's request for grant of a patent on the basis of claims 1 to 15 received on 18 August 2006 with a letter of the same date.

The examining division set out the following reasons for the refusal in the section numbers listed:

15.1. Claim 1 did not comply with Article 84 EPC due to a lack of clarity caused by reference number 26 being used for two different features;

15.2. Claim 1 did not comply with Article 84 EPC in combination with Rule 29(1) and (3) EPC as it did not include the essential feature of the transfer function of the converter;

15.3. The subject-matter of claim 1 lacked an inventive step in view of document **D1 (US 5 475 296)**; and

15.4. The set of claims did not comply with Article 82 EPC as it was not unitary.

III. With the statement of grounds of appeal (letter dated 12 November 2013) the appellant (applicant) filed amended sets of claims and various amended description pages according to a main request and first and second auxiliary requests.

IV. The Board summoned the appellant to oral proceedings to be held on 11 February 2019. In a communication annexed to the summons the Board set out their preliminary observations, stating that:

- The Board tended to share the examining division's view that the two independent apparatus claims 1 and 7 lacked unity and that the same applied to the two independent method claims 12 and 13 (Article 82 EPC);
- The feature "duty ratio by which the voltage is to be converted" did not appear to be directly and unambiguously derivable from the application as filed (Article 123(2) EPC);
- It seemed to be an essential feature that the input and output voltages as measured by the sensors would need to be used as a basis for determining if there was an abnormality in one of the sensors and claim 1 of the main request did not include this essential feature (Article 84 EPC);
- For the control unit to be able to determine the presence of an abnormality in the input or output voltage sensor on the basis of the duty cycle of the switching element, it would also have to know how the ratio of the input and output voltages depended on the duty cycle. This essential feature was not included in the claims (Article 84 EPC). This dependency was determined (at least in certain circumstances) by the topology of the switching converter (i.e. the arrangement of its key components). Auxiliary request 2 seemed to take a step in the direction of defining the converter topology, but did not appear to go far enough in defining the converter topology as it was disclosed.

V. With a letter dated 9 January 2019 the appellant responded to the summons to oral proceedings, submitting arguments in favour of the main and first and second auxiliary requests and filing further sets of amended claims and description pages according to third, fourth and fifth auxiliary requests.

Oral proceedings were held on 11 February 2019 as scheduled. During the oral proceedings the appellant filed a set of claims and description pages 1 to 7 of a new fourth auxiliary request.

The appellant requested finally that the decision under appeal be set aside and that a patent be granted on the basis of the claims of the main request, or of one of the first or second auxiliary requests filed with the statement of grounds of appeal, or of the third auxiliary request filed with the letter of 9 January 2019, or on the basis of:

- claims 1 to 8 of the fourth auxiliary request as filed during the oral proceedings;
- description pages 1 to 7 of the fourth auxiliary request as filed during the oral proceedings and pages 8 to 10 as originally filed;
- drawings pages 1 to 6 as originally filed, subject to a correction in Figure 5.

VI. In so far as is necessary to understand the present decision, the wording of the independent claims of the various requests is reproduced below:

**Main Request**

Apparatus Claim 1

"1. A voltage conversion system provided with a converter (12) that converts a voltage, a control unit (26) that variably controls a duty ratio by which the voltage is to be converted in the converter, an input voltage sensor (20) that detects an input voltage of the converter (12), and an output voltage sensor (22) that detects an output voltage of the converter (12), the system characterized in that

the control unit (26) determines the presence of an abnormality of the input voltage sensor (20) or the output voltage sensor (22) on the basis of the duty ratio by which the voltage is to be converted controlled by the control unit (26)."

Apparatus Claim 7

"7. A voltage conversion system provided with a converter (12) that converts a voltage, a voltage detection means (20, 22) hat [sic] detects one of an input voltage and an output voltage of the converter (12), and a control unit (26) that variably controls a duty ratio by which the voltage is to be converted in the converter (12), the system characterized in that

the control unit (26) estimates one of the input voltage and the output voltage of the converter (12) that has not been detected by the voltage detection means (20, 22) on the basis of the duty ratio by which the voltage is to be converted controlled by the control unit (26)."

Method claims 12 and 13 and computer program product claim 15 do not need to be reproduced.

**First Auxiliary Request**

Apparatus Claim 1

"1. A voltage conversion system provided with a converter (12) that converts a voltage, a control unit (26) that variably controls a duty ratio by which the voltage is to be converted in the converter, an input voltage sensor (20) that detects an input voltage of the converter (12), and an output voltage sensor (22) that detects an output voltage of the converter (12), the system characterized in that

the control unit (26) determines the presence of an abnormality of the input voltage sensor (20) or the output voltage sensor (22) on the basis of the duty ratio by which the voltage is to be converted controlled by the control unit (26), the input voltage of the converter (12) detected by the input voltage sensor (20) and the output voltage of the converter (12) detected by the output voltage sensor (22)."

Method claim 8 and computer program product claim 10 do not need to be reproduced.

**Second Auxiliary Request**

Apparatus Claim 1

"1. A voltage conversion system provided with a converter (12) that converts a voltage, a control unit (26) that variably controls a duty ratio by which the voltage is to be converted in the converter, an input voltage sensor (20) that detects an input voltage of the converter (12), and an output voltage sensor (22) that detects an output voltage of the converter (12), wherein the converter (12) is constituted of a plurality of switching elements (Q1, Q2), and changes in the conversion ratio between the input voltage and output voltage of the converter are only dependent on the duty ratio that [sic] used for operation of the switches (Q1, Q2) of the converter (12), the system characterized in that

the control unit (26) determines the presence of an abnormality of the input voltage sensor (20) or the output voltage sensor (22) on the basis of the duty ratio by which the voltage is to be converted controlled by the control unit (26), the input voltage of the converter (12) detected by the input voltage sensor (20) and the output voltage of the converter (12) detected by the output voltage sensor (22)."

Method claim 8 and computer program product claim 10 do not need to be reproduced.



**Third Auxiliary Request**

Apparatus Claim 1

"1. A voltage conversion system provided with a converter (12) that converts a voltage, a control unit (26) that variably controls a duty cycle of a switching element (Q1, Q2) in the converter, an input voltage sensor (20) that detects an input voltage of the converter (12), and an output voltage sensor (22) that detects an output voltage of the converter (12), the system characterized in that the control unit (26) determines the presence of an abnormality of the input voltage sensor (20) or the output voltage sensor (22) on the basis of the duty cycle controlled by the control unit (26), the input voltage of the converter (12) detected by the input voltage sensor (20) and the output voltage of the converter (12) detected by the output voltage sensor (22)."

Method claim 7 and computer program product claim 9 do not need to be reproduced.

**Fourth Auxiliary Request**

Apparatus Claim 1

"1. A voltage conversion system provided with a converter (12) that converts a voltage, a control unit (26), an input voltage sensor (20) that detects an input voltage of the converter (12), and an output voltage sensor (22) that detects an output voltage of the converter (12),

wherein the converter (12) comprises a first switching element (Q1) and a second switching element (Q2) connected in series, and a coil (L), wherein an emitter of the first switching element (Q1) is connected to an end of the coil (L) and a collector of the first switching element (Q1) is connected to a positive output line of the converter (12), a collector of the second switching element (Q2) is connected to the same end of the coil (L), an emitter of the second switching element (Q2) is connected to a negative line of the converter (12), the input voltage of the converter is connected between the other end of the coil (L) and the negative line of the converter (12), and the output voltage of the converter (12) is connected between the positive output line of the converter (12) and the negative line of the converter (12),

wherein the control unit (26) alternately switches on/off the first and second switching elements (Q1, Q2) by pulse width modulation and variably controls a duty cycle of the first switching element (Q1) , the system characterized in that

the control unit (26) determines the presence of an abnormality of the input voltage sensor (20) or the output voltage sensor (22) on the basis of the duty cycle controlled by the control unit (26), the input voltage of the converter (12) detected by the input voltage sensor (20) and the output voltage of the converter (12) detected by the output voltage sensor (22)."

Method Claim 7

"7. A voltage conversion method of a system comprising a converter (12) that converts a voltage and is controlled to variably change a duty ratio by which the

voltage is to be converted in the converter (12), an input voltage sensor (20) that detects an input voltage of the converter (12), and an output voltage sensor (22) that detects output voltage of the converter (12), wherein the converter (12) comprises a first switching element (Q1) and a second switching element (Q2) connected in series, and a coil (L), wherein an emitter of the first switching element (Q1) is connected to an end of the coil (L) and a collector of the first switching element (Q1) is connected to a positive output line of the converter (12), a collector of the second switching element (Q2) is connected to the same end of the coil (L), an emitter of the second switching element (Q2) is connected to a negative output *[note: the word "output" should have been deleted here]* line of the converter (12), the input voltage of the converter is connected between the other end of the coil (L) and the negative line of the converter (12), and the output voltage of the converter (12) is connected between the positive output line of the converter (12) and the negative line of the converter (12),

wherein the first and second switching elements (Q1, Q2) are alternately switched on/off by pulse width modulation and a duty cycle of the first switching element (Q1) is variably controlled, the method being characterized by comprising:

determining the presence of an abnormality of the input voltage sensor (20) or the output voltage sensor (22) on the basis of the duty cycle, the input voltage of the converter (12) detected by the input voltage sensor (20) and the output voltage of the converter (12) detected by the output voltage sensor (22)."

VII. The appellant's submissions are dealt with in the relevant sections of the reasons for the decision.

## **Reasons for the Decision**

### **1. Main Request**

#### **1.1 *Unity of invention, Article 82 EPC***

1.1.1 The Board shares the examining division's view that the two independent apparatus claims 1 and 7 lack unity and that the same applies to the two independent method claims 12 and 13. The reasons are as follows.

1.1.2 The appellant argued on page 6/9 of the grounds of appeal that "the common inventive concept is to use the duty ratio together with input and/or output voltages to handle a failure event". The Board does not find this argument convincing because there is nothing in claims 7 and 13 that is suggestive of a failure event. Claims 7 and 13 cover a voltage conversion system (and method) which has (or which is carried out with) a converter that only ever comprised one voltage sensor (input or output), i.e. in which there has been no failure event. Hence, such a system/method does not have an inventive concept in common with claims 1 and 12 which relate to the detection of a failure event in a method/system with two voltage sensors (input and output).

1.1.3 In the letter dated 9 January 2019 the appellant argued further that whilst independent claims 7 and 13 did not expressly mention a failure, the measures defined in claims 7 and 13 could be applied for a failure case in which one of the input and output voltages was not detected (see page 2/10, last paragraph). The Board

does not find this argument persuasive. Whilst claims 7 and 13 might be applicable in such a failure case, that does not change the fact that they are also applicable to cases in which the converter only ever comprised one voltage sensor (input or output), i.e. in which there has not been any failure event. It is this aspect, which is covered by claims 7 and 13, that lacks unity with claims 1 and 12.

1.1.4 For these reasons the Board considers that the claims of the main request do not meet the requirement for unity of invention, Article 82 EPC.

1.2 *Clarity, Article 84 EPC*

1.2.1 Further to the above, given that it is not evident what precisely is meant by "duty ratio by which the voltage is to be converted", this formulation itself is not clear. The appellant has argued that it means "the ratio between the input voltage and the output voltage" (grounds for appeal, page 3/9, second paragraph), but the word "duty" makes no sense in that context. In the letter dated 9 January 2019 the appellant argued that this formulation is to be understood as the duty ratio or duty cycle of the switching elements in the converter. The very fact that such conflicting arguments have been presented as to how the formulation is to be understood emphasises that the formulation itself is unclear.

1.2.2 According to claim 1 of the main request the control unit 26 determines the presence of an abnormality of the input voltage sensor 20 or the output voltage sensor 22 just on the basis of the duty ratio by which the voltage is to be converted controlled by the control unit 26. It is evident from the disclosure of

the application as a whole, however, that the control unit 26 would not be able to determine the presence of an abnormality in one of the input and output voltage sensors without having knowledge of the voltages as detected by those sensors. Thus, it is an essential feature of the invention that the input voltage of the converter detected by the input voltage sensor and the output voltage of the converter detected by the output voltage sensor are also used as the basis for determining the presence of an abnormality. The appellant's argument that the use of the input and output voltages forms part of the inventive concept (letter of 9 January 2019, page 2/10, last paragraph) supports the finding that this is an essential feature. Claim 1 of the main request fails to include this essential feature, cf. Rule 43(1) and (3) EPC.

1.2.3 Furthermore, it is evident from the application as a whole that for the control unit to be able to determine the presence of an abnormality in the input or output voltage sensor on the basis of the duty cycle of the switching element and the detected input and output voltages, it would also have to know what the relationship between the input and output voltages should be, depending on the duty cycle. Without knowledge of what this relationship (sometimes referred to as the "transfer function") should be, the control unit would be unable to determine whether or not there is an abnormality in one of the input and output voltage sensors. Claim 1 of the main request fails to include this essential feature, cf. Rule 43(1) and (3) EPC.

1.2.4 For these reasons claim 1 of the main request does not meet the requirements for clarity, Article 84 EPC.

1.3 *Amendments, Article 123(2) EPC*

In view of the Board's findings on Articles 82 and 84 EPC it was not necessary to decide on the question, raised in the Board's communication, of whether the feature "duty ratio by which the voltage is to be converted" is directly and unambiguously derivable from the application as filed (see IV. above).

1.4 *Conclusion on the main request*

For the reasons set out above the Board was not able to accede to the appellant's main request.

2. **First Auxiliary Request**

2.1 In the first auxiliary request, claims 7 to 10 and 13 of the main request have been deleted, thereby removing the lack of unity, Article 82 EPC.

2.2 Furthermore, the essential feature referred to in paragraph 1.2.2 above has been introduced into the independent claims 1 and 8, thereby removing the deficiency under Article 84 EPC referred to in that paragraph.

2.3 Nevertheless, the amendments made according to the first auxiliary request do not address the deficiencies identified in paragraphs 1.2.1 and 1.2.3 above. In view of these deficiencies the Board was not able to accede to the appellant's first auxiliary request.

3. **Second Auxiliary Request**

- 3.1 The amendments made according to the second auxiliary request do not address the deficiencies identified in paragraph 1.2.1 above.
- 3.2 Regarding the deficiency identified in paragraph 1.2.3, the independent claims according to the second auxiliary request specify that the converter is constituted of a plurality of switching elements, and that changes in the conversion ratio between the input voltage and output voltage of the converter are only dependent on the duty ratio that *[is]* used for operation of the switches of the converter.

The Board recognises that in switching converters, at least under certain conditions, the manner in which the relationship between the input and output voltages depends on the duty cycle is determined by the topology of the converter, i.e. the arrangement of its key components. Hence, defining the converter topology has the potential to overcome the deficiency identified in paragraph 1.2.3. Nevertheless, merely specifying that the converter is constituted of a plurality of switching elements does not define the converter topology sufficiently to determine how the relationship between the input and output voltages would depend on the duty cycle. Hence, the amendments according to the second auxiliary request do not overcome the deficiency identified in paragraph 1.2.3 above.

- 3.3 In view of these deficiencies the Board was not able to accede to the appellant's second auxiliary request.



4. **Third Auxiliary Request**

4.1 The amendments made according to the third auxiliary request do not address the deficiency identified in paragraph 1.2.3 above.

4.2 In view of this deficiency the Board was not able to accede to the appellant's third auxiliary request.

5. **Fourth Auxiliary Request**

5.1 With the amendments made according to the fourth auxiliary request, the Board is satisfied that the definition of the converter topology in both of the independent claims is sufficient to clearly define the manner in which the relationship between the input and output voltages would depend on the duty cycle of the first switching element (Q1). With that the deficiency identified in paragraph 1.2.3 above is overcome.

5.2 The converter topology as specified in the independent claims is directly and unambiguously derivable from the application as filed, in particular from figure 1 and the corresponding description. Furthermore, "duty cycle" is the term usually used to refer to the fraction of the commutation period during which the switch of a switching converter is on (see [https://en.wikipedia.org/wiki/Boost\\_converter](https://en.wikipedia.org/wiki/Boost_converter), Circuit analysis, Operation, Continuous Mode) and the use of the duty cycle of the transistor Q<sub>1</sub> located in the upper side of the converter 12 to determine the presence of an abnormality has a basis in paragraph [0035] of the published application. Thus, the amendments according to the fourth auxiliary request

overcome the objection under Article 123(2) EPC raised in the Board's communication (see IV. above).

5.3 *Inventive Step, Article 56 EPC*

5.3.1 Considering inventive step in view of document D1, the Board notes that the D1 converter has four switches and can be put into boost or buck mode by switching two of the transistors permanently on/off as shown in figure 4. In the boost mode the transistor Q1 is on and the transistor Q4 is off. Transistors Q2 and Q3 are connected with respect to the inductor L in the same way as the transistors Q1 and Q2 are connected in the independent claims of the fourth auxiliary request. Furthermore they are switched by anti-phase PWM signals that would switch the two transistors alternately, variably controlling the duty cycle of each transistor. Sensing of input voltage (12) and output voltage (15) is provided by an A/D converter (16).

5.3.2 Hence, document D1 discloses a voltage conversion system that has all of the features of the preambles of claims 1 and 7.

5.3.3 The question remains whether it would be obvious to determine the presence of an abnormality of the input voltage sensor or the output voltage sensor on the basis of the duty cycle controlled by the control unit, the input voltage of the converter detected by the input voltage sensor and the output voltage of the converter detected by the output voltage sensor.

5.3.4 According to the preamble of claims 1 and 7, the duty cycle controlled by the control unit" is the "duty cycle of the first switching element (Q1)" which is

connected between the inductor and the positive output line.

5.3.5 The Board can see no obvious reason for the skilled person starting from document D1 to use the duty cycle of this specific switching element of the converter as a basis for the abnormality check.

5.3.6 With the benefit of hindsight it is perhaps derivable that using the duty cycle of this specific switching element is advantageous. The converter arrangement claimed is that of a boost (step-up) converter that is able to boost the battery voltage  $V_1$  up to the higher voltage  $V_2$  that should exist across the capacitor C (see also paragraph [0004] of the published application). In continuous mode, with the duty cycle of transistor  $Q_2$  represented as  $D_{Q2}$ , the ratio of the output and input voltages in such a boost converter would be (cf. Wikipedia reference above):

$$V_2 / V_1 = 1 / (1 - D_{Q2}) \quad (\text{Equation 1})$$

With the transistor  $Q_1$  switched on and off alternately with transistor  $Q_2$ , in the manner described for the same circuit arrangement in the prior art (see paragraph [0006]), the duty cycle  $D_{Q1}$  of transistor  $Q_1$  would be equal to 1 minus the duty cycle  $D_{Q2}$  of transistor  $Q_2$ , i.e.

$$D_{Q1} = 1 - D_{Q2} \quad (\text{Equation 2})$$

Using this in equation 1, the ratio of the output and input voltages can be represented as:

$$V_2 / V_1 = 1 / D_{Q1} \quad (\text{Equation 3})$$

This can be rewritten as:

$$V_1 = V_2 \times D_{Q1} \quad (\text{Equation 4})$$

From equation 4 it can be seen that the duty cycle of the transistor  $Q_1$  is equal to the ratio of the input and output voltages and thus might provide a convenient basis for the abnormality check of the invention. However this seems only to be evident with the benefit of hindsight.

5.3.7 For these reasons the Board considers that the claims of the fourth auxiliary request meet the requirements for inventive step, Article 56 EPC.

5.4 *Correction in Figure 5*

In figure 5 of the application as filed, the step S31 state "INPUT INVERTER INPUT VOLTAGE V1". This is erroneous and should state "INPUT BATTERY VOLTAGE V1".

5.5 *Conclusion on the fourth auxiliary request*

For the reasons set out above the Board decided to accede to the appellant's fourth auxiliary request.

## Order

### For these reasons it is decided that:

1. The decision under appeal is set aside.
2. The case is remitted to the department of first instance with the order to grant a patent in the following version:
  - claims 1 to 8 of the fourth auxiliary request as filed during the oral proceedings of 11 February 2019;
  - description
    - pages 1 to 7 of the fourth auxiliary request as filed during the oral proceedings of 11 February 2019 and
    - pages 8 to 10 as originally filed;
  - drawings pages 1 to 6 as originally filed, subject to a correction in Figure 5 [*see paragraph 5.4 of the Reasons*].

The Registrar:

The Chairman:



U. Bultmann

R. Lord

Decision electronically authenticated