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(56) Documents Cited:
EP 1548922 A1 **WO 2001/003277 A3**
US 20040264219 A1

(58) Field of Search:
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Other: **WPI, EPODOC**

(54) Abstract Title**: Protection system for a resonant converter with synchronous rectification**

(57) A protection system for a resonant converter comprises sensors 1,2 to measure the voltage across each synchronous rectifier switch Sr1, Sr2 and an override circuit 0C1, 0C2 for each rectifier to override a control signal from a control system when the measured voltage over the opposite rectifier switch is below a predetermined threshold value (fig 2c Vref). The circuit may included a comparator (fig 2c) and the rectifiers can be switched off when overridden, using an AND gate or diodes (fig 2c). The converter may be an LLC resonant converter.

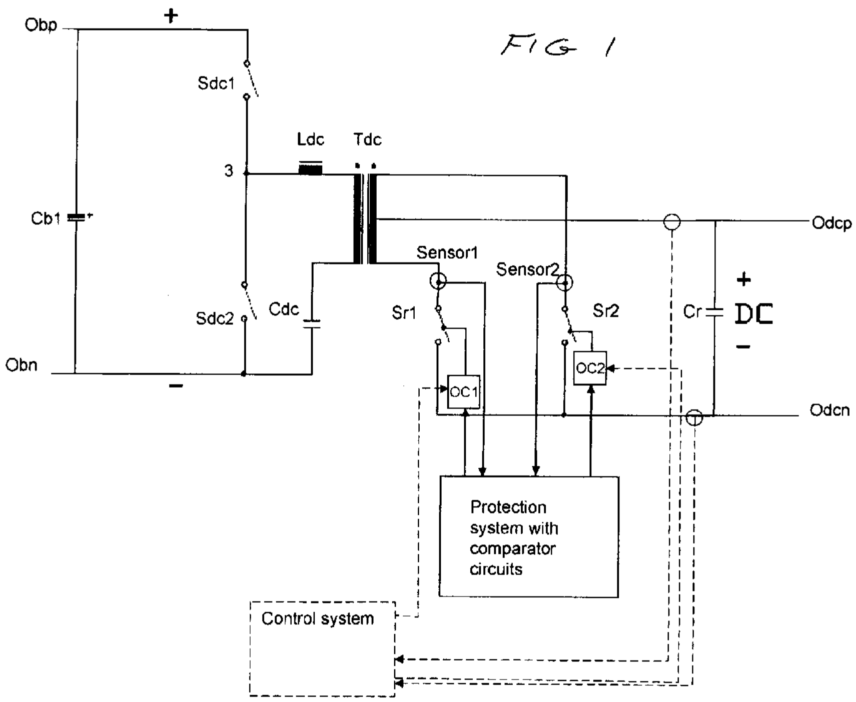

FIG 1

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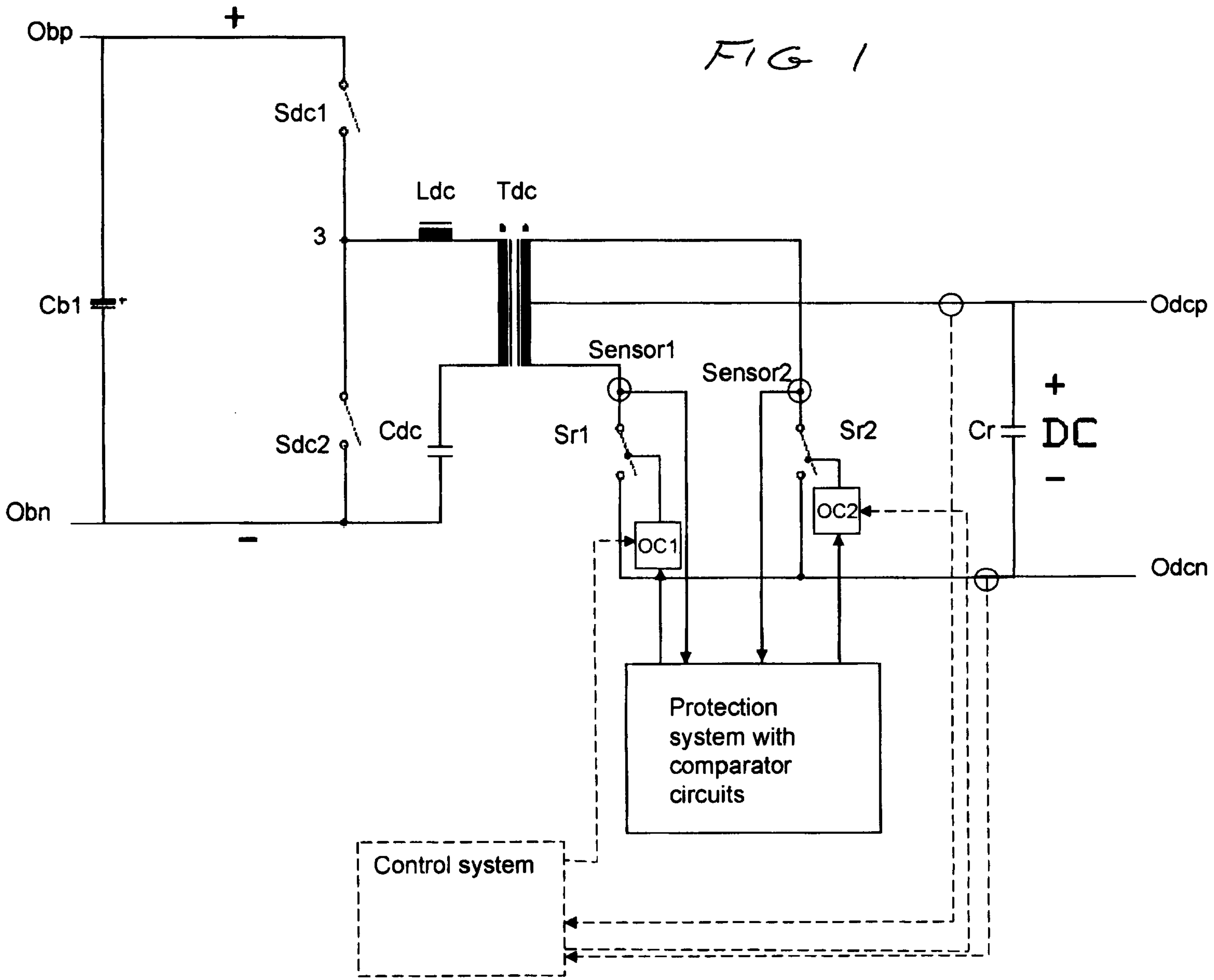
FIG 1


Obp
+
Sdc1
3
Ldc
Tdc
Cb1
Sensor1
Sensor2
Odcp
Sdc2
Cdc
Sr1
Sr2
Cr
+
DC
-
Obn
-
OC1
OC2
Odcn
Protection system with comparator circuits
Control system

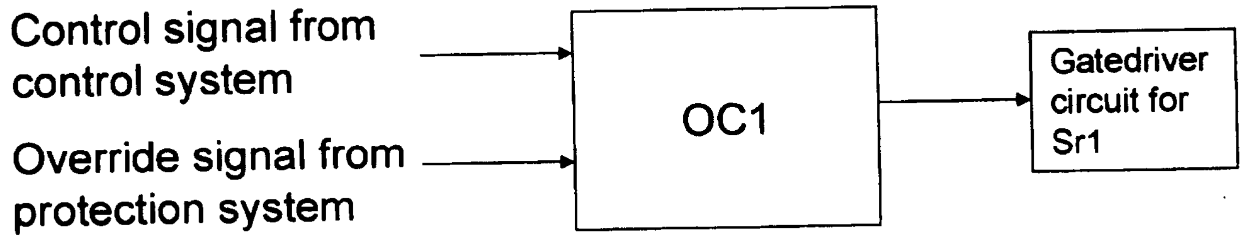


Fig. 2a

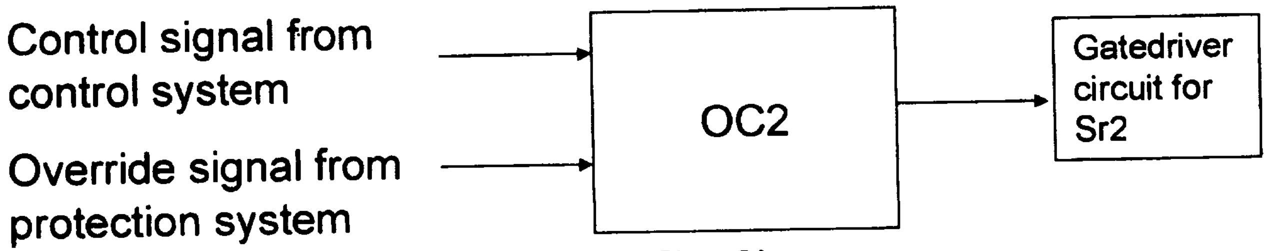
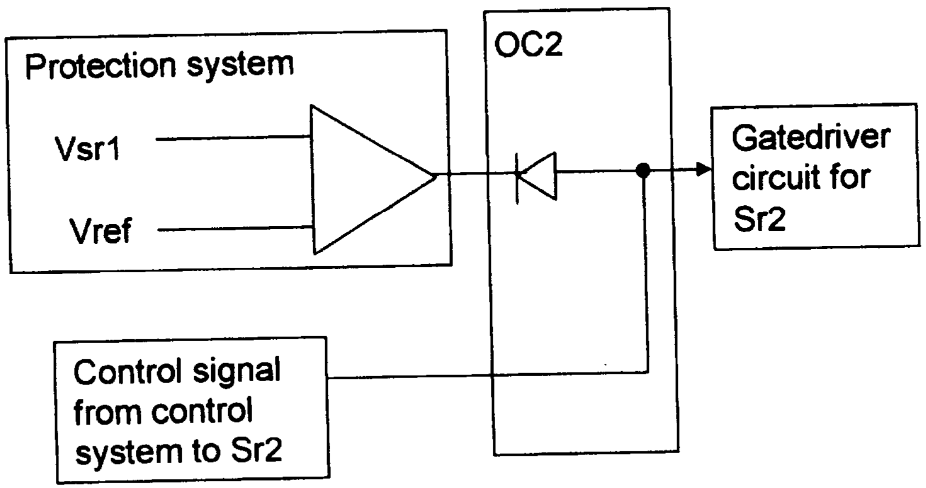


Fig. 2b

Fig. 2c



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Title: Protection system

FIELD OF THE INVENTION

The present invention relates to a protection system for a resonant converter with synchronous rectifiers.

PRIOR ART

Several types of converters are known for use in power supply systems, where there is a need to convert an AC power to a controlled DC power. The AC power will usually be supplied from an AC power source, such as the mains. The DC power is supplied to equipment such as telecommunication equipment, broad band data communication equipment, military equipment, medical equipment etc.

Several such converters are known. For example is a boost converter shown and described in "Power Electronics: converters, applications, and design", 2nd ed., by Mohan, Undeland and Robbins in chapter 7-4. In the same book, different DC-DC converter topologies are described in chapter 10-4 and 10-5. Synchronous rectifiers are also known in the art, to further control the output voltage of power supply systems.

The requirements for the DC power can vary, but usually it is important to keep the DC voltage within certain boundaries and also to protect the DC side from irregularities in the voltage/current on the AC side. Failures may also occur in the load, which causes a surge voltage or current to enter the power supply system from the DC side.

Consequently, it is important to protect both the electrical components of the telecommunication equipment, i.e. the load, and also to protect the electrical components of the power supply system itself.

The switches of the power supply systems are more and more being controlled digitally, for example by means of a programmed digital signal processor (DSP). The DSP receives voltage and current measurements from sensors in the power supply system, and calculates the current state continuously. If one or some of the measurements indicate that a dangerous state has occurred, for example that the input voltage is above a certain level, the DSP provides for that the system goes into a failsafe mode, for example by turning off all switches of the system.

However, there are some disadvantages related to the above control system. The DSP can, in certain situations, be busy with calculations, thereby causing the failsafe mode to be delayed, thereby causing components to be damaged by the surge voltage. Moreover, it has been found difficult to predict all possible failure situations and combinations of failure situations and program those into the DSP.

The object of the invention is to provide an improved protection system where the disadvantages mentioned above are avoided.

SUMMARY OF THE INVENTION

The present invention relates to a protection system for a resonant converter with synchronous rectification, where the resonant converter is comprising a control system for providing control signals to first and second rectifier switches of the converter, characterized in that the protection system comprises:

- a first sensing means for measuring the voltage over the first rectifier switch and a second sensing means for measuring the voltage over the second rectifier switch;

- comparator circuits for comparing the measured voltages from the first and second sensing means with a predetermined threshold value Vref;

- an override circuit for each of the first and second rectifier switches, for overriding the control signal from the control system when the measured voltage over the opposite rectifier switch is below a predetermined threshold value Vref.

In an aspect of the invention, the override circuit comprises a first input terminal receiving the control signal from the control system, a second input terminal receiving an override signal from the comparator circuit, and an output terminal connected to a gate terminal of the rectifier switch either directly or by means of a gate driver circuit.

In an aspect of the invention, the rectifier switch is turned OFF when overridden by the protection system.

In an aspect of the invention, the override circuit for the first rectifier switch receives an override signal when the voltage over the second rectifier switch is below the predetermined threshold value Vref and that the override circuit for the second rectifier switch (Sr2) receives an override signal when the voltage over the first rectifier switch (Sr1) is below the predetermined threshold value Vref.

In an aspect of the invention, the override circuits comprise a logic AND circuit element.

In an aspect of the invention, the override circuits comprise a diode connected with its anode to a gate driver circuit for the second rectifier switch and to the control signal for the second rectifier switch and with its cathode to the output of the comparator circuit.

In an aspect of the invention, the converter is a LLC series resonant converter with synchronous rectification.

The present invention also relates to a resonant converter with synchronous rectification, characterized in that it comprises a protection system as described above.

DETAILED DESCRIPTION

Embodiments of the invention will now be described with reference to the enclosed drawings, where:

Fig. 1 illustrates the topology of a first embodiment of the invention;

Fig. 2a and 2b illustrate an embodiment of the override circuits for the two rectifier switches respectively;

Fig. 2c illustrates an alternative embodiment of the override circuit for one of the rectifier switches.

The first embodiment of the invention is illustrated in fig. 1, where it is shown a DC-DC converter with a synchronous rectifier. More specifically, the converter is a LLC series converter with a synchronous rectifier.

The DC-DC converter would normally be connected to an AC/DC converter (not shown), for example a bridgeless boost converter. In the present embodiment, the input terminals of the DC-DC converter is a positive boost output terminal Obp and a negative boost output terminal Obn of such a bridgeless boost converter. It should be noted that the input terminals can be another DC source, for example the output terminals of another type of AC/DC converter.

A boost capacitor Cb1 is connected between the terminals Obp and Obn, as shown in fig. 1.

The DC-DC converter comprises a first dc-dc switch Sdc1 connected between the positive output terminal Obp of the boost converter and a third node 3 and a second dc-dc switch Sdc2 connected between the negative output terminal Obn of the boost converter and the third node 3.

A dc-dc inductor Ldc is connected between the third node 3 and a first input terminal of a transformer device Tdc. A dc-dc capacitor Cdc is connected between the negative output terminal Obn of the boost converter and a second input terminal of the transformer device Tdc.

The topology on the secondary side or output side of the DC-DC converter is often referred to as a synchronous rectifier.

Here, a first rectifier switch Sr1 is connected between a first output terminal of the transformer device Tdc and a negative dc-dc output terminal Odcn.

A second rectifier switch Sr2 is connected between a second output terminal of the transformer device Tdc and the negative dc-dc output terminal Odcn.

A positive dc-dc output terminal Odcp is connected directly to a third output terminal of the transformer device Tdc. The third output terminal is an output terminal between the first and second output terminals, and consequently, the voltage level at the third terminal is between the voltage levels at the first and second terminals. In the present embodiment, the number of windings between the first and third terminal is half of the number of windings between the first and second terminals.

A rectifier capacitor Cr is connected between the positive dc-dc output terminal Odcp and the negative dc-dc output terminal Odcn.

The converter comprises a control system (illustrated with dashed lines) for controlling the first and second rectifier switches Sb1, Sb2. The control system will also be controlling the dc-dc switches Sdc1, Sdc2 (even though not shown in fig. 1). The operation of the control system is based on input from sensors that measures voltages and/or currents in the converter. In fig. 1 it is shown that the output voltage over the rectifier capacitor Cr is used as an input to the control system, however, other parameters can be used as well. The control system can be of a type that is known for a man skilled in the art, and will not be described here in detail.

The control system controls the switches to provide an optimal (i.e. regarding quality, regarding specified voltage and current output etc) output power to the positive and negative dc-dc output terminals Odcp, Odcn.

The elements of the protection system according the present embodiment are illustrated in fig. 1. The protection system comprises a first sensing means or first sensor 1 and a second sensing means or second sensor 2. The first sensor 1 is measuring the voltage Vsr1 over the first rectifier switch Sr1. The second sensor 2 is measuring the voltage Vsr2 over the second rectifier switch Sr2.

The protection system also comprises first and second override circuits OC1 and OC2, as shown in fig. 1. Also the control signals from the control system are input to the respective override circuits. The override circuits will be described in detail below.

Moreover, the protection system uses a reference voltage Vref for the voltage over the respective rectifier switches Sr1 and Sr2. The reference voltage Vref will be dependent of the components that are chosen in the topology, however, it must be so large that dangerous operation is avoided, and at the same time should not be to large to reduce power efficiency.

The protection system also comprises comparator circuits to provide a comparison of the following parameters to provide the override functionality:

1: If Vsr1 < Vref, then disable control signal to the second rectifier switch Sr2. If not, enable control signal to rectifier switch Sr2. The protection system provides this by an override signal to the second override circuit OC2.

2: If Vsr2 < Vref, then disable control signal to the first rectifier switch Sr1. If not, enable control signal to rectifier switch Sr1. The protection system provides this by an override signal to the first override circuit OC1.

It should be noted that the override signal for the first rectifier switch Sr1 is based on the voltage measurement of the second sensor 2 and the override signal for the second rectifier switch Sr2 is based on the voltage measurement of the first sensor 1.

As mentioned above, the protection system comprises an override circuit OC1, OC2 for each of the respective rectifier switches Sr1, Sr2. The override circuit could for example comprise a logic AND circuit element, where the control signal from the control system and the override signal from the protection system are input to the logic AND circuit element, and where the output of the logic AND circuit element is connected directly to the trigging or gate terminal of the respective switch, according to points 1 and 2 above, or to a gatedriver circuit for the respective switches, to ensure that the voltage or current at the gate terminal of the switch is sufficient to turn the switches ON/OFF. Override circuits for the first and second switch Sr1 and Sr2 are illustrated in fig. 2a and 2b respectively.

In this configuration, the default output of the protection system would be logic 1, i.e. no override of the control system, and the switch will be turned ON and OFF depending on the control signal (logic 1 and logic 0 respectively). If a dangerous state is detected by the protection system, the output of the protection system would be logic 0 and consequently the output of the logic AND circuit element would also be logic 0. Hence, the output trigging signal would change to logic 0, i.e. the switch will be turned OFF independent of the control signal from the control system.

As known for a man skilled in the art, a logic AND functionality could be implemented in many ways, also by means of an analogue circuit. Such an embodiment is illustrated in fig. 2c for switching the second rectifier switch Sr2. Here, the protection system is shown to comprise a comparator means by means of a comparator for comparing the voltage reference Vref and the voltage Vsr1 over the first switch Sr1. The second override circuit OC2 comprises a diode connected with its anode to the gate driver circuit for Sr2 and to the control signal for the second switch Sr2 from the control system and with its cathode to the output of the protection system. Hence, if the protection system detects a dangerous state, i.e. Vsr1 < Vref, the output of the comparator turns to a state LOW, and consequently, the control signal from the control system is clamped to zero by means of the diode of the second override circuit OC2. If no dangerous state is detected, i.e. Vsr1 is not less than Vref, the comparator turns to a state HIGH, and consequently, the control signal is forwarded to the gate driver circuit.

It should be noted that the first override circuit OC2 can be provided correspondingly to the second override circuit described above.

According to the present embodiment, the protection system is independent of the control system, since both systems are provided with separate inputs and separate control functionality. The connection to the input terminals of the override circuits is what they have in common.

CLAIMS

1. Protection system for a resonant converter with synchronous rectification, where the resonant converter is comprising a control system for providing control signals to first and second rectifier switches (Sr1, Sr2) of the converter, characterized in that the protection system comprises:

- a first sensing means (1) for measuring the voltage over the first rectifier switch (Sr1) and a second sensing means (2) for measuring the voltage over the second rectifier switch (Sr2);

- comparator circuits for comparing the measured voltages from the first and second sensing means (1,2) with a predetermined threshold value Vref;

- an override circuit (OC1, OC2) for each of the first and second rectifier switches (Sr1, Sr2), for overriding the control signal from the control system when the measured voltage over the opposite rectifier switch (Sr1, Sr2) is below a predetermined threshold value Vref.

2. System according to claim 1, characterized in that the override circuit comprises a first input terminal receiving the control signal from the control system, a second input terminal receiving an override signal from the comparator circuit, and an output terminal connected to a gate terminal of the rectifier switch either directly or by means of a gate driver circuit.

3. System according to claim 1, characterized in that the rectifier switch is turned OFF when overridden by the protection system.

4. System according to claim 1, characterized in that the override circuit for the first rectifier switch (Sr1) receives an override signal when the voltage over the second rectifier switch (Sr2) is below the predetermined threshold value Vref and that the override circuit for the second rectifier switch (Sr2) receives an override signal when the voltage over the first rectifier switch (Sr1) is below the predetermined threshold value Vref.

5. System according to claim 1, characterized in that the override circuits (OC1, OC2) comprise a logic AND circuit element.

6. System according to claim 1, characterized in that the override circuits (OC1, OC2) comprise a diode connected with its anode to a gate driver circuit for the second rectifier switch (Sr2) and to the control signal for the second rectifier switch (Sr2) and with its cathode to the output of the comparator circuit.

7. System according to claim 1, characterized in that the converter is a LLC series resonant converter with synchronous rectification.

8. Resonant converter with synchronous rectification, characterized in that it comprises a protection system according to any of claims 1 – 7.

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Application No: GB0724431.2 **Examiner:** Robert Barrell

Claims searched: 1-9 **Date of search:** 10 April 2008

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-8	WO01/03277 A3 (SYNQOR) See: the abstract; figs 16 and 18; and page 18, lines 14-28
X	1-8	US2004/0264219 A1 (ZHANG) See: paragraph 186; and figs 24 and 25
A	-	EP1548922 A1 (SONY) See: whole document

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

H02H; H02M

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
H02M	0001/32	01/01/2007
H02H	0007/127	01/01/2006
H02M	0003/335	01/01/2006