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Additional inventors are being named on the _____ separately numbered sheets attached hereto		
TITLE OF THE INVENTION (500 characters max):		
Coil-to-coil Signal Transfer		
Direct all correspondence to: CORRESPONDENCE ADDRESS		
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ENCLOSED APPLICATION PARTS (check all that apply)		
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Date 4th September 2007

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Docket Number: 1052-3

Coil to Coil Signal Transfer

Field of the Invention

The present invention is directed to providing a system and method for transferring a digital signal between the coils of an inductive energy coupling.

5 Background

When providing power to electric devices it is often desirable to provide a channel for signal transfer. A signal transfer channel may be useful for example for power regulation or the like. Thus a communication channel is often provided alongside the power input. Known methods for providing such a communication
10 channel include wired connections to the device, which may be packaged in the same cable as the power lines.

Many devices such as transformers or induction connectors transfer energy using inductive energy transfer between a primary induction coil and a secondary induction coil. In order to regulate parameters of the transmitted power such as
15 voltage, current, temperature and the like, feedback of these parameters from the device to the power source is essential. However where the primary coil and secondary coil must remain galvanically isolated a wired connection is not suitable.

In order to avoid electrical contact wireless systems may be used to transfer signals between a transmitter and a receiver. For example optocouplers may have a
20 light emitting diode serving as a transmitter which sends encoded optical signals over short distances to a photo-transistor which serves as a receiver. However, an optocoupler typically needs to be aligned such that there is a line-of-sight between transmitter and receiver. In systems where alignment between the transmitter and receiver may be problematic, optocoupling is inappropriate, however alternative
25 communication channels are available. These include ultrasonic signals transmitted by piezoelectric elements, radio signals such as Bluetooth, WiFi and the like.

United States Patent Application Number 2004/0150934 to Barmaan describes an adaptor which has a contactless power interface for receiving power from a contactless power supply and a power regulator for supplying power to a remote
30 device. In Baarman's system, a communication link is provided within the remote device. However the communication link requires a signal transmitter and signal receiver separate from the power transmission mechanism.

An alternative method of feedback in a flyback power converter is described in United States Patent Number 4,996,638 to Orr. Orr's method provides regulation in power conversion equipment, where power regulation is implemented on the primary side of a transformer used to provide isolation of a power source from the load. The
5 feedback mechanism utilizes current perturbations which are summed with the primary current in the power transformer. These perturbations are transformed with the load current to the primary side of the power transformer and extracted using signal processing means to regenerate a useful signal which is isolated from the load.

Orr describes a method of passing a feedback signal through the power
10 transmission coils of a transformer for the purposes of regulating a flyback power converter. Orr's method may be used to transfer perturbation signals but does not provide for the transfer of any external data.

There is a need for a system for transferring a digital transmission signal between the coils of an inductive energy coupling and the present invention addresses
15 this need.

Summary of the Invention

It is therefore an aim of the present invention to disclose a signal transfer system for transferring a transmission signal regarding an electric load connectable via an inductive energy coupling to a power source, said inductive energy coupling comprising a primary coil connectable to the power source in inductive alignment with a secondary coil connectable to the electric load, the system comprising at least one ancillary load; at least one switching unit comprising a modulator for modulating a bit-rate signal with an input signal to create a modulated signal and a switch for intermittently connecting said ancillary load to said secondary coil according to said modulated signal; at least one current monitor for monitoring primary current drawn by said primary coil and producing a primary current signal, and at least one correlator for cross-correlating said primary current signal with said bit-rate signal for producing an output signal.

Preferably, the switching unit further comprises a controller configured to encode data into said input signal.

Typically, the switching unit further comprises a frequency divider.

Preferably, the inductive energy coupling transfers energy with a driving frequency and said bit rate frequency is an integer fraction of said driving frequency.

Optionally, the inductive energy coupling being a device selected from the group comprising: a transformer, a DC-to-DC converter, an AC-to-DC converter, an AC-to-AC converter, a flyback transformer, a flyback converter, a full-bridge converter, a half-bridge converter, a buck converter, a boost converter, a buck-boost converter, a sepic converter and a zeta converter.

Typically, said primary coil being galvanically isolated from said secondary coil.

Optionally, the input signal carrying encoded data pertaining to at least one of the group comprising:

- presence of the electric load;
- required operating voltage for said electric load;
- required operating current for said electric load;

- required operating temperature for said electric load;
 - measured operating voltage for said electric load;
 - measured operating current for said electric load;
 - measured operating temperature for said electric load, and
- 5 • a user identification code.

It is a further aim of the invention to present a contactless inductive coupling comprising the signal transfer system wherein the primary coil is embedded in a power jack and the secondary coil is embedded in a power plug galvanically isolated from the power jack.

- 10 An additional aim of the invention is to teach a method for transferring a signal through an inductive energy coupling, said inductive energy coupling comprising a primary coil connected to a power source and a secondary coil connected to an electric load, said method comprising:

- providing an input signal;
- 15 • providing a bit-rate signal;
- modulating the bit-rate signal with the input signal to create a modulated signal;
- connecting an ancillary load to said secondary coil intermittently according to said modulated signal;
- 20 • monitoring a primary current drawn by said primary coil and producing a primary current signal; and
- cross-correlating said primary current signal with said bit-rate signal to generate an output signal.

- 25 According to one aspect of the invention a method for regulating power transfer across a contactless inductive coupling is taught wherein said output signal provides details of power requirements of said load.

Typically said input signal is provided by encoding data regarding at least one power requirement of said electric load into said input signal.

Optionally one power requirement is selected from the group comprising operating voltage, operating current and operating temperature.

Alternatively the input signal is provided by monitoring at least one operating parameter of said electric load and encoding monitored parameter data into said input
5 signal.

Optionally the parameter being selected from the group comprising operating voltage, operating current and operating temperature.

Typically the method for transferring a signal through an inductive energy coupling includes a preliminary step of detecting the presence of an electric load.

10

Brief Description of the Figures

For a better understanding of the invention and to show how it may be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings.

5 With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no
10 attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention; the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice. In the accompanying drawings:

 Fig. 1 is a schematic diagram showing a system for transferring a transmission
15 signal through an inductive energy coupling in accordance with one embodiment of the present invention;

 Fig. 2 is a schematic diagram showing the transmission circuit of the embodiment of Fig. 1 in more detail;

 Fig. 3 is a schematic diagram showing the exemplary reception circuit of the
20 embodiment of Fig. 1 in more detail;

 Fig. 4 is a schematic diagram showing the microcontroller of the reception circuit controlling the switch of a flyback converter;

 Fig. 5 is a schematic diagram showing the signal transfer system integrated into a contactless inductive power coupling system, and

25 Fig. 6 is a flowchart showing a method for transferring a transmission signal through an inductive energy coupling in accordance with the invention.

The same numbering scheme is used throughout the Figures.

Description of the Preferred Embodiments

Reference is now made to Fig. 1 which shows a signal transfer system 100 for transferring a transmission signal through an inductive energy coupling 30. The inductive energy coupling 30 consists of a primary coil L_1 which may be connected to a power source 10 and a secondary coil L_2 , galvanically isolated therefrom, across which an electric load 20 may be connected either directly or via an AC-DC converter 22.

A transmission circuit 40 may be connected in parallel with the electric load 20. The transmission circuit 40 comprises an ancillary load 42 connected to the secondary coil L_2 via a switching unit 44. Typically the ancillary load 42 is much smaller than the electric load 20.

A corresponding reception circuit 60 is connected to the primary coil L_1 of the inductive energy coupling 30 and comprises a current monitor 62, such as an ammeter in series with the primary coil L_1 , and a correlator 64.

The switching unit 44 is configured to receive an input signal S_{in} and a bit-rate signal F_b . A modulator (not shown) modulates the bit-rate signal F_b with the input signal S_{in} to produce a modulated signal S_M . The ancillary load 42 is intermittently connected to the secondary coil 20 at a rate determined by the modulated signal S_M .

The power source 10, such as an alternating-current voltage source, intermittent directcurrent voltage source or the like, is configured and operable to produce a primary voltage V_1 which oscillates at a driving frequency F_d . The oscillating primary voltage V_1 in coil L_1 induces a secondary voltage $V_2(t)$ in the secondary coil L_2 . The secondary voltage $V_2(t)$ is optionally passed through an AC-DC converter 22 producing a direct-current voltage $V_{22}(t)$.

The electric load 20 which is coupled to the secondary coil L_2 either directly or via the AC-DC converter 22 draws a load current I_{22} . The power P_{22} provided to the load 20 is given by the scalar product of the voltage V_{22} with the load current I_{22} . When the ancillary load 44 is connected, an additional ancillary current i_{24} is also drawn. Thus, with the ancillary load 44 connected, the total power P_2 drawn by the secondary coil L_2 is given by:

$$P_2(t) = \vec{V}_{22}(t) \bullet [\vec{I}_{22} + \vec{i}_{24}(t)]$$

where the ancillary current signal $i_{2d}(t)$ varies with the modulated signal S_M .

The input power $P_1(t)$ provided to the primary coil L_1 is given by:

$$P_1(t) = \bar{V}_1(t) \bullet \bar{I}_{10}(t)$$

5 where the primary voltage $V_1(t)$ oscillates at the driving frequency F_d which is determined by the power supply 10.

Input power $P_1(t)$ provided by the primary coil L_1 is generally proportional to the total power $P_{22}(t)$ drawn by the secondary coil L_2 , and the primary voltage $V_1(t)$ is determined by the power supply. Perturbations in the primary current $I_{1d}(t)$ supplied to the primary coil L_1 are thus in proportion with $i_{2d}(t)$.

10 The current monitor 62 monitors the primary current $I_{1d}(t)$ over time, producing a primary current signal S_p which typically has similar characteristics to the modulated signal S_M . The correlator 64 is configured to cross-correlate the primary current signal S_p with the bit rate F_b . The output signal S_{out} of the correlator 64 therefore has the same characteristics as the input signal S_{in} .

15 In this manner, information carried by the input signal S_{in} is transmitted from the transmission circuit 40 and is retrievable by the receiver circuit 60 from the output signal S_{out} . It is noted that the signal transfer system 100 described herein, transmits a transmission signal across the same inductive power coupling 30 as used for power transmission. This is in contradistinction to prior art transmission systems, which use
20 additional elements to provide signal transmission channels separate from the power transmission channels. In consequence of this innovative approach, additional transmission elements such as optocouplers, piezoelectric elements, supplementary coil pairs and the like are not generally required.

25 With reference now to Fig. 2, an exemplary transmission circuit 40 of the signal transfer system 100 of Fig. 1 is shown. An AC-to-DC converter 22 having a diode 222 and a capacitor 224 is connected in parallel to the secondary coil L_2 smooths an AC secondary voltage V_2 from the secondary coil L_2 into a DC load voltage V_{22} which is connected across an electric load 20.

30 The connection between the ancillary load 42 and the load voltage V_2 is controlled by a switching unit 44 which includes a frequency divider 442, microcontroller 444 and a switch 446. The frequency divider 442 provides the bit-rate

signal F_b which is passed to the microcontroller 444. The microcontroller 444 is configured to modulate the bit-rate signal F_b according to input signals including control signals S_C from the electric load 20 and external signals S_E , as described hereinbelow.

5 Control signals S_C are used to regulate the power supply. Control signals S_C provide data relating to load parameters. Typically these include the required operating voltage, current and temperature and the actual measured operating voltage, current and temperature as monitored during operation of the load.

10 External Signals S_E may be used to provide the transmission circuit 40 with external data to be digitally encoded into the input signal S_{in} by the microcontroller 444 and transmitted to the receiver circuit 60. External information may for example provide useful supplementary data such as a user identification code, a pass key, battery level of the load device and the like..

15 It will be appreciated that the ability to transmit supplementary information, such as external signals S_E through the induction energy coupling 30 presents a further advantage over prior art systems which are only suitable for transmitting control signals.

20 Fig. 3 is a schematic representation of an exemplary receiver circuit 60 in accordance with Fig. 1, consisting of a current monitor 62, a frequency divider 66, a correlator 64 and a microcontroller 68. The frequency divider 66 provides the bit-rate signal F_b which is typically an integer fraction of the driving frequency F_d . The current monitor 62 provides a primary current signal S_P which is passed to the correlator 64 for cross correlation with the bit-rate signal F_b . The resulting output signal S_{out} is passed to a microcontroller 68 which may use the output signal S_{out} to
25 pass a control signal S_C to control the power source 10 so as to regulate the power provided to the electric load 20. The microcontroller 68 may also be used to extract external signals S_E from the output signal.

30 An exemplary use of the receiver circuit 60 of Fig. 3 is highlighted in Fig. 4 which shows the receiver circuit 60 configured to control a flyback power source 10F. In a flyback converter, a direct current voltage source 12 is intermittently connected to a primary coil L_1 by a switch 14. This produces a varying voltage signal $V_1(t)$ in the primary coil L_1 which induces a secondary voltage V_2 in a secondary coil L_2 (Fig. 1).

The secondary coil L_2 is generally connected to a smoothing circuit such the AC-DC converter 22 shown in Fig. 2 to produce a DC output.

5 The switch 14 is controlled by a driver 18 which receives a pulsing signal F_d from a clock 16. The pulsing signal F_d determines the frequency with which the direct current voltage source 12 is connected to the primary coil L_1 . The power delivered to the primary coil L_1 may be regulated by varying the duty cycle of the switch 14. The duty cycle is the proportion of the time between pulses during which the switch 14 is closed.

10 Whereas, in prior art flyback converters, additional elements such as optocouplers or the like have been used to transmit feedback signals. Fig. 4 shows the innovative use of the signal transfer system 100 which receives a feedback signal transferred between the primary and secondary power transmission coils and received by the receiver circuit 60. The microcontroller 68 generates a control signal S_C which is relayed to the driver 18. The control signal S_C determines the duty cycle of the switch 14 and so may be used regulate power transmission.

15 Although only a flyback converter is represented in Fig. 4 it is noted that a control signal S_C thus transmitted may be used to regulate power transfer in a variety of transmission assemblies such as a transformer, a DC-to-DC converter, an AC-to-DC converter, an AC-to-AC converter, a flyback transformer, a full-bridge converter, a half-bridge converter or a forward converter for example.

20 As an example of its application, with reference to Fig. 5, the signal transfer system 100 (Fig. 1) may be integrated into a contactless inductive power coupling system 500 where power is inductively transmitted from a jack unit J to a plug unit P galvanically isolated therefrom. A transmission circuit 40 embedded in the plug unit P may be used to transmit transmission signals S to a receiver circuit 60 in the jack J. Thus once the primary L_1 and secondary L_2 coils are aligned, control signals may be passed between the plug P and jack J units with no need to align any additional components such as optocouplers for example.

25 Where a contactless plug P is used, for example to power a portable computer PC having on-board power cells 520, the signal transfer system 100 may be used to detect the presence of the load PC producing a detection signal S_{DL} and then to provide the jack J with signals relating to the identity of the user S_{ID} and the serial

number S_{SN} or other identifier of the laptop computer PC. Signals regarding the operating voltage and current required by the PC may be provided as a signal S_Q which may also provide supplementary information such as information related to the power level of the cells, for example. Using this signal S_Q , the signal transfer system
5 100 may be used to select between powering the computer PC directly, recharging the power cells 520 thereof or both depending on defaults and predetermined criteria. It is further noted that when used for recharging cells 520, the ability to monitor the temperature of the cells 520 during recharging may be used to prevent overheating.

Referring to Fig. 6, a flowchart showing a method for transferring a
10 transmission signal through an inductive energy coupling in accordance with one embodiment of the invention, and with further reference to Fig. 1, an Input Signal S_{in} – Step (a) and a Bit-rate Signal F_b – Step (b) are provided to the transmission circuit 40. The Bit-rate Signal F_b is then modulated by the Input Signal S_{in} producing a Modulated Signal S_M – Step (c). An ancillary load 42 is then connected to the second
15 coil L_2 intermittently according to the Modulated Signal S_M – Step (e). The receiver circuit 60 monitors the primary current drawn by the primary coil L_1 to produce a Primary Current Signal S_P – Step (e). This Primary Current Signal S_P is then cross-correlated with the Bit-rate Signal F_b to generate an Output Signal S_{out} – Step (f).

In this manner, information regarding a load 20 hardwired to a plug P is
20 transmitted to the power source 10 across the power jack J using the inductor coils L_1 and L_2 of the inductive coupling 30 created by aligning the plug P and jack J, as a signal superimposed on the power transmitted, without requiring additional data transmitting components.

The basic signal feedback system and method described hereinabove are
25 capable of variation. Thus the scope of the present invention is defined by the appended claims and includes both combinations and sub combinations of the various features described hereinabove as well as variations and modifications thereof, which would occur to persons skilled in the art upon reading the foregoing description.

In the claims, the word “comprise”, and variations thereof such as
30 “comprises”, “comprising” and the like indicate that the components listed are included, but not generally to the exclusion of other components.

Claims

1. A signal transfer system for transferring a transmission signal regarding an electric load connectable via an inductive energy coupling to a power source, said inductive energy coupling comprising a primary coil connectable to the power source in inductive alignment with a secondary coil connectable to the electric load, the system comprising:
 - a. at least one ancillary load;
 - b. at least one switching unit comprising a modulator for modulating a bit-rate signal with an input signal to create a modulated signal and a switch for intermittently connecting said ancillary load to said secondary coil according to said modulated signal;
 - c. at least one current monitor for monitoring primary current drawn by said primary coil and producing a primary current signal; and
 - d. at least one correlator for cross-correlating said primary current signal with said bit-rate signal for producing an output signal.
2. The signal transfer system of Claim 1, wherein the switching unit further comprises a controller configured to encode data into said input signal.
3. The signal transfer system of Claim 1, wherein said switching unit further comprises a frequency divider.
4. The signal transfer system of Claim 1, wherein said inductive energy coupling transfers energy with a driving frequency and said bit rate frequency is an integer fraction of said driving frequency.
5. The signal transfer system of Claim 1, said inductive energy coupling being a device selected from the group comprising: a transformer, a DC-to-DC converter, an AC-to-DC converter, an AC-to-AC converter, a flyback transformer, a flyback converter, a full-bridge converter, a half-bridge converter and a forward converter.
6. The signal transfer system of Claim 1, said primary coil being galvanically isolated from said secondary coil.
7. The signal transfer system of Claim 1, said input signal carrying encoded data pertaining to at least one of the group comprising:

- a. presence of the electric load;
 - b. required operating voltage for said electric load;
 - c. required operating current for said electric load;
 - d. required operating temperature for said electric load;
 - 5 e. measured operating voltage for said electric load;
 - f. measured operating current for said electric load;
 - g. measured operating temperature for said electric load, and
 - h. a user identification code.
8. A contactless inductive coupling comprising the signal transfer system of Claim 1,
- 10 wherein the primary coil is embedded in a power jack and the secondary coil is embedded in a power plug galvanically isolated from the power jack.
9. A method for transferring a signal through an inductive energy coupling, said inductive energy coupling comprising a primary coil connected to a power source and a secondary coil connected to an electric load, said method comprising:
- 15 a. providing an input signal;
- b. providing a bit-rate signal;
- c. modulating the bit-rate signal with the input signal to create a modulated signal;
- d. connecting an ancillary load to said secondary coil intermittently according
- 20 to said modulated signal;
- e. monitoring a primary current drawn by said primary coil and producing a primary current signal; and
- f. cross-correlating said primary current signal with said bit-rate signal to generate an output signal.
- 25 10. The method of Claim 9 for regulating power transfer across a contactless inductive coupling wherein said output signal provides details of power requirements of said load.
11. The method of Claim 9 for regulating power transfer across a contactless inductive coupling wherein said input signal is provided by encoding data

regarding at least one power requirement of said electric load into said input signal.

- 5 12. The method of Claim 10, said at least one power requirement being selected from the group comprising operating voltage, operating current and operating temperature.
13. The method of Claim 9 for regulating power transfer across a contactless inductive coupling wherein said input signal is provided by monitoring at least one operating parameter of said electric load and encoding monitored parameter data into said input signal.
- 10 14. The method of Claim 12, said at least one parameter being selected from the group comprising operating voltage, operating current and operating temperature.
15. The method of Claim 9 comprising the preliminary step of detecting the presence of an electric load.

Fig. 1

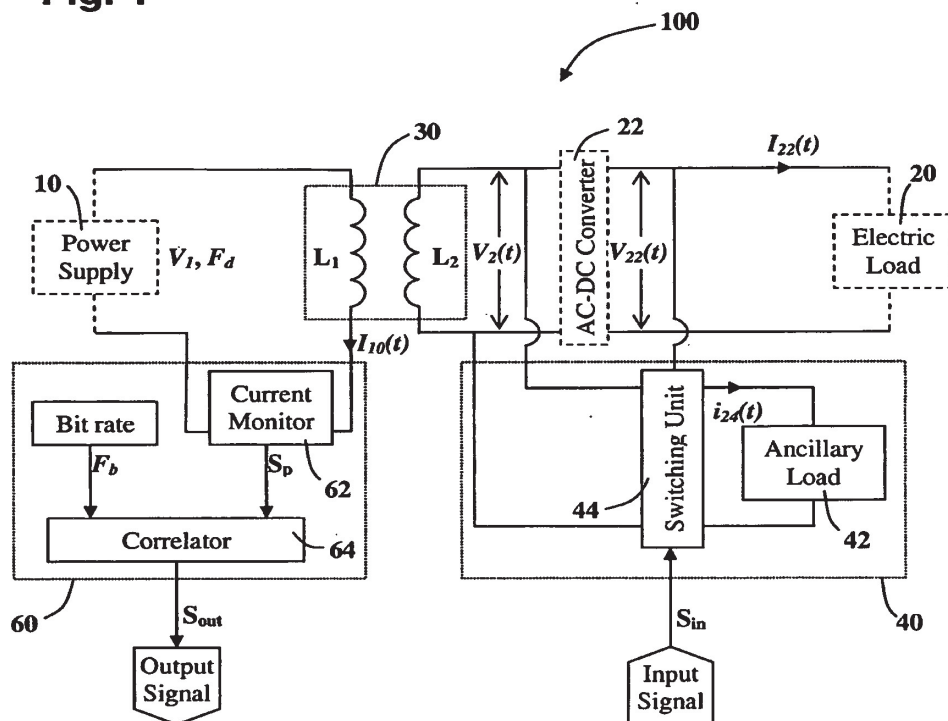


Fig. 2

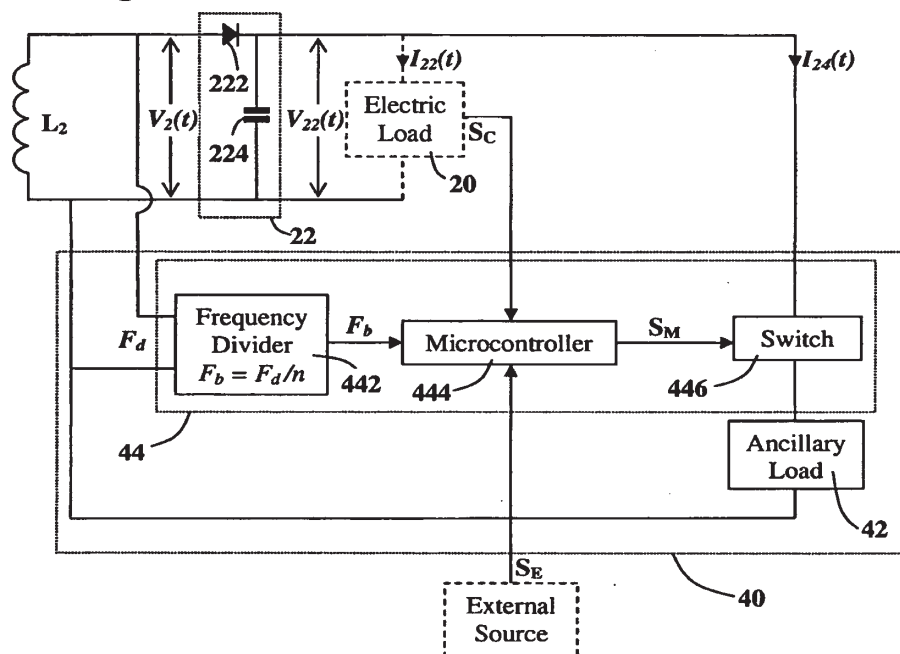


Fig. 3

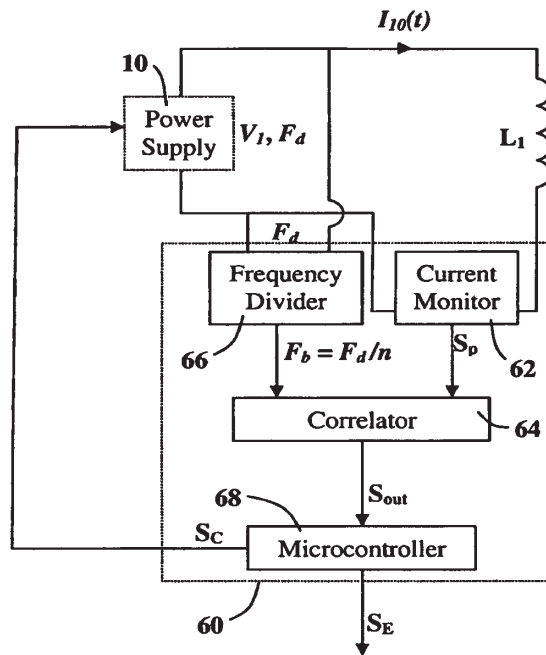


Fig. 4

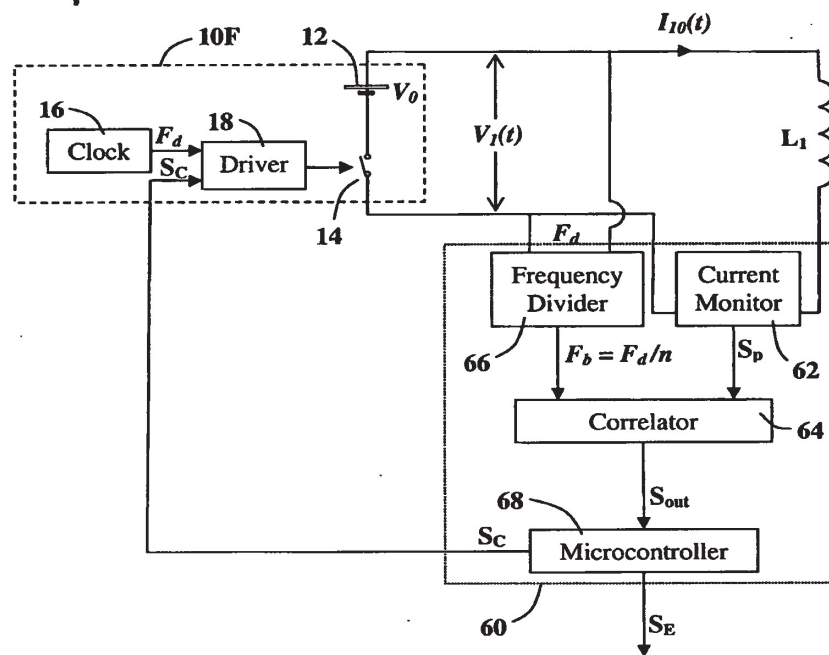


Fig. 5

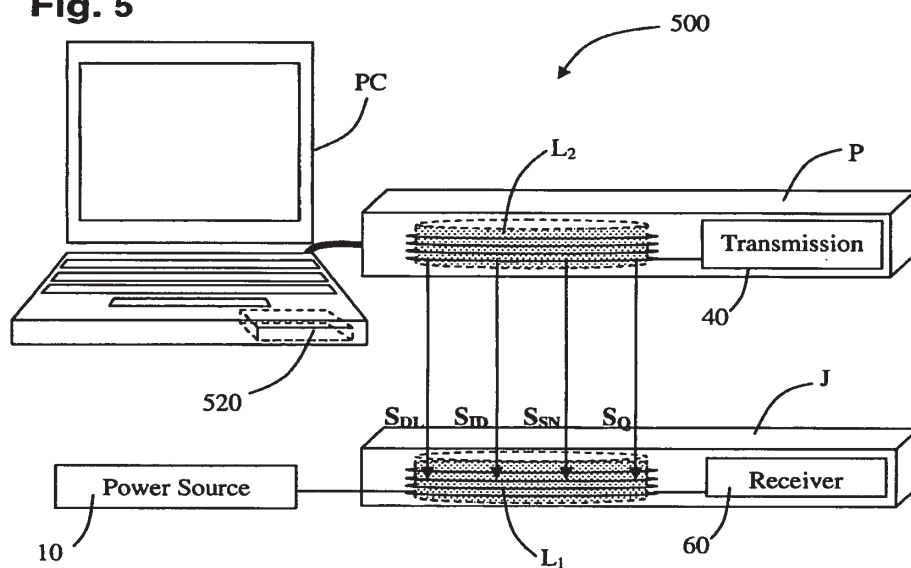


Fig. 6

