

## TITLE OF THE INVENTION

Method and Apparatus for Active Isolation in Inductive Loop Detectors

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention generally relates to the measurement of inductance, and more particularly to inductive vehicle detectors.

## 2. Description of the Related Art

Inductive wire-loop vehicle detectors of the prior art are typically based on the Colpitts oscillator using a wire-loop sensor. A simple wire-loop has two terminals that are typically connected to the rest of the detector circuit through a pair of lead wires. The lead wires connected to the primary coil of a transformer serving as a common-mode choke typically having 40dB common-mode noise attenuation. The secondary coil of the transformer is connected to a capacitor effectively forming an inductance-capacitance-resistance (LCR) circuit with the wire-loop.

In the typical Colpitts oscillator-based detector, one leg of the LCR circuit is connected to a positive direct current (DC) power supply terminal. Because of this arrangement, the common-mode noise appearing at the secondary coil of the transformer is converted to differential noise as the common-mode current flowing through the leg of the secondary coil tied to the positive power-supply terminal is drained away. Consequently, the common-mode current flowing through the other leg of the secondary coil charges the capacitor of the LCR circuit. These current flows create a differential noise voltage, which is added to the existing differential noise on the circuit. The largest component of common-mode noise is typically

1 power-line noise around 60Hz. For a typical two-meter loop having three  
2 turns of wire, the differential noise induced by a 60Hz power line is at 60Hz  
3 and its harmonics. The primary method for canceling ambient noise in prior-  
4 art detectors is to integrate the sampling period of the detector over a time  
5 chosen to coincide with the local power-line voltage period.

6 Additionally, where multiple wire-loop sensors are placed in close  
7 proximity, crosstalk is a concern. Crosstalk between detectors is a function  
8 of the inductive coupling between the wire-loops and the transformers as  
9 well as the relative phase and amplitudes of the oscillating signals on the  
10 loops. The primary method for mitigating the effects of crosstalk in prior-art  
11 detectors is to use different capacitance values in the LCR circuits. This  
12 tends to randomize the relative phase of the oscillating signals on adjacent  
13 loops over time.

14 The primary methods for minimizing crosstalk and canceling ambient  
15 noise described above tend to limit the sampling rate of prior-art wire-loop  
16 sensors to approximately 60Hz, which is well below what is desirable for  
17 recording repeatable inductive signatures on vehicles traveling at highway  
18 speeds.

19

## 20 BRIEF SUMMARY OF THE INVENTION

21 It is desirable to isolate signal from noise in an inductive vehicle  
22 detector. Inductance is typically measured indirectly as a function of the  
23 resonant frequency of an LCR circuit in which the oscillation frequency is  
24 approximately inversely proportional to the square root of the product of  
25 inductance and capacitance. In practice, significant errors in the  
26 measurement of this oscillation frequency are typical.

27 In the absence of noise errors, the measured inductance of a wire-loop  
28 is independent of the polarity of the excitation current used to make the LCR  
29 circuit oscillate. However, when random and non-random differential noise  
30 is induced into the circuit, typically through the wire-loop, lead-wire, and  
31 transformer, the resulting inductance measurement errors strongly depend  
32 on the polarity of the excitation current. By employing an oscillator circuit  
33 having two balanced capacitors and by controlling the polarity of the  
34 excitation current, the effects of common-mode and differential noise can be  
35 greatly reduced with minimal effect on the inductance measured at the wire-

1 loop sensor.

2

### 3 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

4 The above-mentioned features of the present invention will become  
5 more clearly understood from the following detailed description of the  
6 invention read together with the drawings in which:

7 Figure 1 illustrates a block diagram of one embodiment of the  
8 oscillator circuit of the present invention;

9 Figure 2 illustrates a block diagram of an alternate embodiment of the  
10 oscillator circuit of the present invention;

11 Figure 3 is a schematic diagram of the oscillator circuit embodied in  
12 Figure 1;

13 Figure 4 is a simplified schematic diagram of the oscillator circuit  
14 embodied in Figure 3;

15 Figure 5a is a graphic representation of one output of the oscillator  
16 circuit of the present invention using the circuit of Figure 3;

17 Figure 5b is a graphic representation of the other output of the  
18 oscillator circuit of the present invention using the circuit of Figure 3;

19 Figure 5c is a graphic representation of the output of Figure 5a  
20 overlain with the output of Figure 5b;

21 Figure 5d is a graphic representation of the pulse-train output of the  
22 differential comparator of the circuit of Figure 3;

23 Figure 6 is a graphic representation of inductive signature data  
24 obtained using the oscillator circuit of the present invention;

25 Figure 7 is a graphic representation of an array of inductive loop  
26 sensors disposed in a speed-trap configuration; and

27 Figure 8 is a graphic representation of inductive signature data  
28 obtained using a prior art oscillator circuit.

29

### 30 DETAILED DESCRIPTION OF THE INVENTION

31 An oscillator circuit for use in an inductive vehicle detector is shown  
32 generally at **10** in the Figures. Inductance is typically measured indirectly  
33 as a function of the frequency of an LCR oscillator in which the oscillation  
34 frequency is approximately inversely proportional to the square root of the  
35 product of inductance and capacitance. In practice, significant errors in the

1 measurement of this oscillation frequency are typical. In the absence of  
2 noise errors, the measured inductance of a wire-loop is independent of the  
3 polarity of the excitation current driving the oscillation of the LCR circuit.  
4 However, both random and non-random differential noise induced into the  
5 circuit cause inductance measurement errors, which have a polarity that is  
6 strongly dependent on the polarity of the excitation current.

7 Figure 1 illustrates a block diagram of one embodiment of an  
8 inductive vehicle detector including the oscillator circuit **10** of the present  
9 invention. The vehicle detector includes an inductive loop sensor **100**.  
10 Those skilled in the art will recognize the various configurations that may be  
11 used for the inductive loop sensor **100**. A simple inductive loop sensor **100**  
12 is a wire-loop having two terminals connected to the rest of the detector  
13 circuit through a pair of lead wires. Alternatively, the wire-loop is connected  
14 to the primary coil of a transformer serving as a common-mode choke **102**,  
15 as illustrated in Figure 1. The secondary coil of the transformer is connected  
16 to a resistance-capacitance (RC) circuit **104** forming an inductance-  
17 capacitance-resistance (LCR) circuit with the wire-loop **100**. Typically,  
18 connecting the wire-loop through a common-mode choke **102** provides  
19 approximately 40dB of common-mode noise attenuation. An excitation  
20 circuit **108** interruptably connects a voltage supply **110** to the secondary  
21 coil of the common-mode choke **102**. In the illustrated embodiment, the  
22 oscillating output of the oscillator circuit **10** is passed to a measuring device  
23 **112** that samples the frequency of the oscillation at any given time. The  
24 frequency of the oscillation in turn relates to the inductance of the wire-loop  
25 **100**. The measuring device **112** includes a differential comparator **106**  
26 whose output switches whenever the differential output of the oscillator  
27 circuit **10** changes polarity. The measuring device **112** also includes a  
28 counter **114** that counts the pulses generated by a high-speed, fixed-  
29 frequency clock **116** gated by the differential comparator **106**. These  
30 measurements are then processed by a processing device **118** to extract  
31 useful information from the data.

32 The excitation circuit **108** is typically implemented using a plurality of  
33 switches. These switches are gated by precisely timed digital signals that are  
34 generated by a timing source **120**. In one embodiment, the timing source  
35 **120** is implemented using a binary counter that counts the high-speed clock

1 source **116**. Typically, the binary counter **120** is initialized to zero at the  
2 start of a measurement cycle and the counter proceeds to count each  
3 successive pulse from the clock source. When a predetermined count is  
4 reached, a gate signal is generated to turn on one pair of switches and  
5 counting continues until a second predetermined count is reached at which  
6 time the gate signal is terminated to turn off the pair of switches. The  
7 measurement cycle is complete when a third predetermined count is  
8 reached, and a new cycle begins.

9 Figure 2 illustrates a block diagram of an alternate embodiment of the  
10 oscillator circuit **10'** of the present invention. In the illustrated embodiment,  
11 the measuring device **112** is replaced by a differential sample-and-hold  
12 amplifier **200** feeding an analog-to-digital converter (ADC) **202**. The  
13 differential sample-and-hold amplifier **200** combined with the ADC **202**  
14 provide greater flexibility over the frequency measuring device **112** in the  
15 aforementioned embodiment by sampling the entire differential output of the  
16 oscillator circuit **10**, as opposed to only sampling the zero crossings. To  
17 develop a baseline, the decaying sinusoids are sampled at multiple points  
18 which allows a determination of the base resistance and inductance of the  
19 inductive sensor. This baseline sampling need only occur once, but can be  
20 repeated to monitor the oscillator circuit **10** for baseline drift, which, for  
21 example, can be caused by temperature variations. Thereafter, the decay  
22 sinusoids are sampled to determine the change in the inductance of the  
23 wire-loop **100** due to the presence of a vehicle or other metal object. Again,  
24 the measurements are processed by a processing device **118** to extract  
25 useful information from the data.

26 Figure 3 is a schematic diagram of the oscillator circuit **10** embodied  
27 in Figure 1. The oscillator circuit **10** is an inductance-capacitance-  
28 resistance (LCR) oscillator having two legs. In the illustrated embodiment,  
29 each leg including a resistance **R<sub>1</sub>**, **R<sub>2</sub>** in series with a capacitor **C<sub>1</sub>**, **C<sub>2</sub>**.  
30 Those skilled in the art will recognize that **R<sub>1</sub>**, **R<sub>2</sub>** can represent the inherent  
31 resistance of the circuit or discrete resistors selected to balance the circuit.  
32 The RC circuit **104** is coupled to a wire-loop sensor **100** used as a sensor.  
33 In the illustrated embodiment, the wire-loop sensor **100** includes an  
34 inherent inductance **L<sub>L</sub>** and a resistance **R<sub>L</sub>** connected via the common-mode  
35 choke **102**. Again, those skilled in the art will recognize that **R<sub>L</sub>** and **L<sub>L</sub>**

1 typically represent the inherent inductance and resistance of the wire loop  
2 and that discrete components are not typically used. Further, those skilled  
3 in the art will recognize that the wire-loop sensor **100** may be directly  
4 connected to the RC circuit if desired, without departing from the scope and  
5 spirit of the present invention. Each leg of the oscillator **10** is connected to  
6 an input of the differential comparator **106**. Because two capacitors **C<sub>1</sub>**, **C<sub>2</sub>**  
7 are used in this LCR oscillator **10**, rather than the single capacitor that is  
8 typical of the prior-art, the oscillator output resembles the Caduceus, hence  
9 it is useful to refer to the circuit of the present invention as a Caduceus  
10 oscillator **10**.

11 The two capacitors **C<sub>1</sub>**, **C<sub>2</sub>** prevent the common-mode noise passed  
12 through the common-mode choke **102** from being converted into differential  
13 noise, as occurs in conventional oscillator circuits used for inductive  
14 sensors. In the illustrated embodiment, the common-mode noise from the  
15 common-mode choke **102** appears as a common-mode voltage at the  
16 Caduceus oscillator outputs **304a**, **304b**. This common-mode voltage is  
17 rejected with a high attenuation by either the differential comparator **106** or  
18 the differential sample-and-hold circuit **200**. Those skilled in the art will  
19 recognize that while the common terminal **306** of the two capacitors **C<sub>1</sub>**, **C<sub>2</sub>**  
20 is depicted as connected to a biasing voltage **V<sub>HS</sub>** at one-half of the power  
21 supply voltage in Figure 3, the common terminal **306** can be fixed at a  
22 different voltage potential, if desired. By using a biasing voltage **V<sub>HS</sub>**, it is  
23 possible to use a single positive supply voltage supply without the need for a  
24 negative voltage supply and, further, prevents the voltage between the  
25 capacitors **C<sub>1</sub>**, **C<sub>2</sub>** from floating.

26 The excitation circuit **108** includes two pairs of switches **302a**, **302b**  
27 arranged in a bipolar charging arrangement with one switch **S<sub>1</sub>**, **S<sub>3</sub>** of each  
28 switch pair **302** connected to a voltage supply **V<sub>s</sub>** and the other switch **S<sub>2</sub>**, **S<sub>4</sub>**  
29 connected to ground. The switch pairs **302** are arranged in a totem-pole  
30 configuration. In one embodiment, the switches **S<sub>1</sub>-S<sub>4</sub>** are implemented  
31 using power metal-oxide semiconductor field effect transistors (MOSFETs);  
32 however, those skilled in the art will recognize that other switches may be  
33 used without departing from the scope and spirit of the present invention.  
34 The voltage supply **V<sub>s</sub>** is a direct current (DC) power supply producing a  
35 positive voltage and, typically, the supply voltage to each switch pair **302** is

1 the same.

2 There are several allowable switching configurations of the switches  
 3 **S<sub>1</sub>-S<sub>4</sub>** in Figure 3. First, all switches **S<sub>1</sub>-S<sub>4</sub>** are opened to allow the Caduceus  
 4 oscillator **10** to oscillate freely. Second, the ground-connected switches **S<sub>2</sub>,**  
 5 **S<sub>4</sub>** are closed to quench the Caduceus oscillator **10** to ground. Third, the  
 6 voltage supply connected switches **S<sub>1</sub>, S<sub>3</sub>** are closed to quench the Caduceus  
 7 oscillator **10** to the positive supply voltage. Finally, a voltage-supply-  
 8 connected switch **S<sub>1</sub>, S<sub>3</sub>** from one switch pair **302** and a ground-connected  
 9 switch **S<sub>2</sub>, S<sub>4</sub>** from the other switch pair **302** are momentarily closed to  
 10 charge the Caduceus oscillator **10** to a given polarity depending on the  
 11 desired direction of current flow through the excitation circuit **108**. For ease  
 12 of discussion, the set of switches represented by switches **S<sub>1</sub>** and **S<sub>4</sub>** and the  
 13 set of switches represented by switches **S<sub>2</sub>** and **S<sub>3</sub>** will be referred to as the  
 14 first set and the second set, respectively. It is undesirable for both switches  
 15 of either switch pair **302** to be closed simultaneously, i.e., both **S<sub>1</sub>** and **S<sub>2</sub>**  
 16 closed or both **S<sub>3</sub>** and **S<sub>4</sub>** closed.

17 When the Caduceus oscillator **10** is charged, the voltage on the  
 18 capacitors **C<sub>1</sub>, C<sub>2</sub>** is initialized very close to the power supply voltage and  
 19 practically all of the accumulated noise voltage from the previous cycle is  
 20 eliminated. When the Caduceus oscillator **10** is decoupled from the power  
 21 supply and begins to oscillate, any common-mode or differential noise  
 22 currents present in the circuit, integrated over observed time, produce an  
 23 accumulating noise voltage on the capacitors. Accordingly, it is desirable to  
 24 sample the Caduceus oscillator outputs **304** soon after the power supply is  
 25 decoupled so that less accumulated noise will be present [i.e., the  
 26 accumulated noise increases while the sinusoid decays].

27 Figure 4 illustrates a simplified schematic diagram of the Caduceus  
 28 oscillator **400** shown in Figure 3. The equation describing the Caduceus  
 29 oscillator **400** in the time domain is

$$30 \quad v_c(t) = [v_1(0^+) + v_2(0^+)] \left[ e^{-\frac{R}{2L}t} \sqrt{1 + \frac{\left(\frac{R}{2L}\right)^2}{\left(\sqrt{\frac{1}{LC_s} - \left(\frac{R}{2L}\right)^2}\right)^2}} \cos \left[ \sqrt{\frac{1}{LC_s} - \left(\frac{R}{2L}\right)^2} t - \tan^{-1} \left( \frac{\frac{R}{2L}}{\sqrt{\frac{1}{LC_s} - \left(\frac{R}{2L}\right)^2}} \right) \right] \right] u(t)$$

31 (1)

1 where  $C_s = \frac{C_1 C_2}{C_1 + C_2}$ . If the circuit is very underdamped, the differential  
 2 voltage input to the comparator can be rewritten as

$$3 \quad v_c(t) = \left[ v_1(0^+) + v_2(0^+) \right] e^{\frac{R}{2L}t} \cos\left( \frac{t}{\sqrt{LC_s}} \right) u(t) \quad (2)$$

4 The inputs to the differential comparator are illustrated graphically in  
 5 Figures 5a-5c. Figures 5a and 5b represent the respective inputs to the  
 6 positive and negative terminals of the differential comparator. Figure 5c  
 7 illustrates the input of Figure 5a overlain with the input of Figure 5b. The  
 8 sinusoidal decay produced by momentarily closing the first set of switches  
 9 **S<sub>1</sub>, S<sub>4</sub>** is depicted at t=0.3 milliseconds and t=0.9 milliseconds and the  
 10 opposite polarity sinusoidal decay produced by momentarily closing the  
 11 second set of switches **S<sub>2</sub>, S<sub>3</sub>** is depicted at t=0.0 milliseconds, and t=0.6  
 12 milliseconds in Figures 5a-5c.

13 When a differential comparator **106** is used, the frequency of the  
 14 Caduceus oscillator **10** is measured by timing the comparator output pulse-  
 15 train, as illustrated in Figure 5d. One method of timing the pulse-train is  
 16 counting a high-speed clock **116** with a counter **114** gated by the pulse-  
 17 train, as illustrated in Figure 1. The counter **114** can be gated on the leading  
 18 edge, the trailing edge, or both the leading and trailing edges of the  
 19 comparator output pulse-train. In one embodiment the counter **114** is gated  
 20 on both edges. In the illustrated embodiment, two or more gated counts are  
 21 added together to produce a summed count having reduced quantization  
 22 error relative to any single gated count. However, it should be noted that, for  
 23 a pulse-train having a given number of zero-crossings per cycle, only the  
 24 second half of the counts captured by the counter **114** are summed because  
 25 discontinuities arise in the inductive signatures when more than the last  
 26 half of the captured counts are double integrated.

27 Bipolar charging is useful for active isolation of the Caduceus  
 28 oscillator frequency measurements from ambient noise **606** and crosstalk  
 29 errors **608**, as in Figure 6, which illustrates inductive signature data  
 30 obtained using an array of wire-loop sensors and the Caduceus oscillator of  
 31 the present invention. Because induced currents are a significant cause of  
 32 most ambient noise **606** and crosstalk errors **608**, these errors have a

1 distinct polarity. This is especially true for differential errors, which are the  
2 most difficult errors to deal with. On the other hand, the frequency of the  
3 oscillation is independent of its polarity.

4 Ambient noise **606** is actively isolated from the oscillator frequency  
5 **602a, 602b, 604a, 604b** measurement by alternating the polarity of the  
6 excitation voltages on successive frequency measurement cycles. By  
7 alternating the excitation polarity, errors due to low-frequency ambient noise  
8 **606** become largely equal and opposite on alternating measurement cycles.  
9 Low-frequency ambient noise **606** is effectively canceled by adding any two  
10 adjacent and oppositely polarized inductive measurements together.  
11 Alternatively, low-frequency ambient noise is quantified by subtracting any  
12 two adjacent and oppositely polarized inductive measurements from each  
13 other.

14 Crosstalk **608** between two or more inductively coupled wire-loop  
15 sensors induces a non-random error into the frequency measurement of  
16 each detection cycle. This non-random error has a polarity attribute similar  
17 to that of ambient noise. Crosstalk errors are cancelled by alternating the  
18 relative polarity of the excitation circuits of inductively coupled detectors. By  
19 adding any two or more adjacent samples obtained from inductively coupled  
20 wire-loop sensors having oppositely polarized excitation circuits, crosstalk is  
21 substantially cancelled and by subtracting any two or more adjacent  
22 samples together the effect of the crosstalk error is quantified. Those skilled  
23 in the art will recognize that other mathematical functions for combining  
24 successive samples derived using different phase-permutations of the  
25 excitation circuit **108** are within the scope of the present invention.

26 The bipolar excitation circuit **108** produces two polarity, or phase,  
27 permutations for the wire-loop sensor. For an array having any number,  $n$ ,  
28 of inductively coupled wire-loop sensors, each having a bipolar excitation  
29 circuit, it is possible to actively isolate the frequency measurement error due  
30 to any crosstalk path within the array. By way of example, consider an  
31 array of two inductively coupled wire-loops, as shown in Figure 7. Figure 7  
32 illustrates the wire-loop sensor array having two 2-meter wire-loops **A, B**  
33 separated by a distance of approximately 2-meters and a vehicle **C**. If wire-  
34 loop **A** and wire-loop **B** are simultaneously excited and allowed to oscillate  
35 with any arbitrary set of polarities (e.g., loop A, negative polarity and loop **B**,

1 negative polarity, there would be non-random errors,  $e[f(A)]$ ,  $e[f(B)]$ , in the  
2 frequency measurements,  $f(A)$ ,  $f(B)$ , due to crosstalk on the inductively  
3 coupled path.

4 Referring now to Figure 6, a set of four inductive signatures **602a**,  
5 **602b**, **604a**, **604b** were recorded from the automobile **C** passing over the  
6 wire-loop sensor array **A**, **B**. The present invention actively isolates the non-  
7 random frequency measurement errors due to crosstalk for the inductively  
8 coupled wire-loops by proper selection of the excitation phases of each wire-  
9 loop sensor **A**, **B** in the array on successive samples. In the inductive  
10 signature data shown in Figure 6, the non-random frequency measurement  
11 errors are actively isolated by exciting the array on successive cycles with a  
12 different set of phase permutations, e.g., wire-loop **A**, positive polarity; wire-  
13 loop **B**, negative polarity and wire-loop **A**, negative polarity; wire-loop **B**,  
14 negative polarity. Providing inductively coupled wire-loop sensors **A**, **B**  
15 within an array with differing polarities inverts the non-random frequency  
16 measurement errors due to crosstalk and the non-random frequency errors  
17 are inverted relative to the original phase permutation. The central traces  
18 **602c**, **604c** represent the estimated inductive signatures after crosstalk  
19 errors **608** have been accounted for through active isolation by averaging  
20 each pair of traces **602a**, **602b**; **604a**, **604b**. The trace pairs **602a**, **602b**;  
21 **604a**, **604b** represent the raw inductive signature data recorded by the wire-  
22 loop sensor circuits as each of the possible excitation circuit phase  
23 permutations were sequenced through on successive samples and  
24 exemplifies crosstalk quantification through active isolation. The sinusoid  
25 lines overlying the trace pairs represent the ambient noise **606**. Those  
26 skilled in the art will recognize that crosstalk may be substantially canceled  
27 or quantified by active isolation in an array having any number of  
28 inductively coupled wire-loops through the use of suitably chosen phase-  
29 permutation sequences similar to that described for a two-loop array.

30 The vertical scale for these signatures represents frequency. In the  
31 absence of a vehicle, these two wire-loop sensor circuits have significantly  
32 different oscillation frequencies. As the test vehicle passes over the loops,  
33 the frequencies converge indicating that the crosstalk errors **608** are  
34 partially a function of the relative frequencies of the two oscillations.

35 Contrast the inductive signature data obtained using the present

1 invention with the inductive signature data obtained with a prior art LCR  
2 oscillator circuit, as shown in Figure 8. In the prior art, the inability to vary  
3 the polarity of the oscillations between measurement cycles removes the  
4 ability to eliminate crosstalk errors between inductively coupled loops as  
5 only one set of raw data **900** at a single polarity is obtained. Further, the  
6 sampling rate of the prior art circuit is limited to the power line frequency  
7 and ambient noise above the power line frequency can not be eliminated.  
8 Trace **902** represents the true inductive signature for comparison with the  
9 raw data **900**.

10       While one embodiment has been shown and described, it will be  
11 understood that it is not intended to limit the disclosure, but rather it is  
12 intended to cover all modifications and alternate methods falling within the  
13 spirit and scope of the invention as defined in the appended claims.

## CLAIMS

Having thus described the aforementioned invention, we claim:

- 1           1.     An oscillator circuit for use in an inductive sensor, said  
2 oscillator circuit comprising:  
3           a first capacitor;  
4           a second capacitor in electrical communication with said first  
5 capacitor;  
6           a wire-loop coupled to each of said first capacitor and said second  
7 capacitor;  
8           a voltage supply;  
9           an excitation circuit connectable with said first capacitor and said  
10 second capacitor to connect said voltage supply to said first capacitor and  
11 said second capacitor at a selected polarity; and  
12           wherein either of said first capacitor and said second capacitor is  
13 charged to a preselected voltage by said excitation circuit and the other of  
14 said first capacitor and said second capacitor is discharged when said  
15 excitation circuit is connected and each of said first capacitor and said  
16 second capacitor is discharged when said excitation circuit is disconnected  
17 to produce a pair of decaying oscillations having a caduceus-shaped output.
- 1           2.     The oscillator circuit of Claim 1 wherein said excitation circuit  
2 is a plurality of switches.
- 1           3.     The oscillator circuit of Claim 2 wherein said oscillator circuit  
2 includes a ground such that when a first of said plurality of switches is  
3 closed, one of said first capacitor and said second capacitor is connected to  
4 said voltage source and when said a second of said plurality of switches is  
5 closed, the other of said first capacitor and said second capacitor is  
6 connected to a ground.
- 1           4.     The oscillator circuit of Claim 1 further comprising a  
2 transformer having a first coil and a second coil, said first coil electrically  
3 connected to said wire loop and said second coil in electrical communication  
4 with said first capacitor and said second capacitor whereby said wire loop is

5 inductively coupled to each of said first capacitor and said second capacitor.

1           5.     An oscillator circuit for use in an inductive sensor, said  
2 oscillator circuit comprising:  
3           a wire-loop;  
4           a resistance-capacitance network coupled to said wire-loop, said  
5 resistance-capacitance network including at least two capacitors;  
6           a voltage supply; and  
7           an excitation circuit connectable to said resistance-capacitance  
8 network to connect said resistance-capacitance network to said voltage  
9 source at a selected polarity;  
10          wherein said resistance-capacitance network is charged to a  
11 preselected voltage by said excitation circuit when said excitation circuit is  
12 connected and said resistance-capacitance network is discharged when said  
13 excitation circuit is disconnected to produce a pair of decaying oscillations  
14 having a caduceus-shaped output.

1           6.     The oscillator circuit of Claim 5 wherein said excitation circuit  
2 is a plurality of switches.

1           7.     The oscillator circuit of Claim 6 wherein said oscillator circuit  
2 includes a ground such that when a first of said plurality of switches is  
3 closed, one of said at least two capacitors is connected to said voltage source  
4 through said resistance-capacitance network and when said a second of said  
5 plurality of switches is closed, the other of said at least two capacitors is  
6 connected to said ground through said resistance-capacitance network.

1           8.     The oscillator circuit of Claim 5 further comprising a  
2 transformer having a first coil and a second coil, said first coil in electrical  
3 communication with said wire-loop and said second coil in electrical  
4 communication with said resistance-capacitance network whereby said  
5 transformer inductively couples said wire loop to said resistance-capacitance  
6 network.

1           9.     A method for actively isolating noise in an inductive vehicle

2 detector, said method comprising the steps of:  
3 (a) selecting a polarity of a voltage source to produce a polarized  
4 voltage output;  
5 (b) exciting a first capacitor using said polarized voltage output;  
6 (c) discharging a second capacitor;  
7 (d) isolating said first capacitor and said second capacitor from said  
8 voltage source;  
9 (e) oscillating said first capacitor and said second capacitor;  
10 (f) measuring a voltage of each of said first capacitor and said second  
11 capacitor;  
12 (g) producing an output signal related to a voltage differential between  
13 said first capacitor voltage and said second capacitor voltage;  
14 (h) terminating a measurement cycle when said first capacitor voltage  
15 and said second capacitor voltage are substantially equal and stable; and  
16 (i) repeating said steps of selecting a polarity of the voltage source to  
17 said step of terminating a measurement cycle.

1 10. The method of Claim 11 wherein said step of producing an  
2 output signal includes the step of generating a pulse when said voltage  
3 differential alternates polarity.

1 11. The method of Claim 11 further comprising the step of  
2 canceling noise by summing any two of said output signal produced in a  
3 successive pair of said measurement cycles.

1 12. The method of Claim 11 further comprising the step of  
2 quantifying noise by subtracting any two of said signal produced in a  
3 successive pair of said measurement cycles.

1 13. An oscillator circuit for use in an inductive sensor, said  
2 oscillator circuit comprising:  
3 means for measuring changes in an inductive field;  
4 means for storing a charge;  
5 means for exciting said means for storing the charge;  
6 means for interruptably connecting said means for charging to said

7 means for storing the charge;  
8 means for alternating a polarity of said means for exciting said means  
9 for storing the charge;  
10 means for discharging said means for storing the charge;  
11 means for measuring a voltage differential of said means for storing  
12 the charge;  
13 means for producing an output signal related to said voltage  
14 differential; and  
15 means for determining a frequency of said output signal.