

# ZGUS Spice Modeling

## 1. Document

### Document information

Info	Content
<b>Keywords</b>	SPICE, Coils, Inductance, VLF
<b>Abstract</b>	<p>SPICE electronic models to explain reverse polarity VLF metal detector coil anomalies are made. Anomalies point to 'asymmetrical capacitance' arising from coil lead capacitance through the way a ground lead is connected is an explaining factor.</p> <p>Differential amplifiers do not require precisely matched resistors to remain functional.</p>

### Software and Document Revisions

Rev	Date	Description
0.5	26 March 2008	Connection with previous results made. Documentation improved
	21 March 2008	Modeling with knowledge of coil interior
	15 January 2008	Initial modeling without full knowledge of coil interior

### Document Locations

The current version of this document can be accessed from [http://www.zgus.com/spice/zgus\\_spice\\_modelling.pdf](http://www.zgus.com/spice/zgus_spice_modelling.pdf)

This document is distributed as zgus\_spice\_modeling.pdf with spice files downloadable from <http://www.zgus.com/spice>

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This information applies to incomplete work. Analysis and conclusions are subject to change.

PREVIEW

## 2. Contents

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<b>1. DOCUMENT</b>	<b>1</b>
<b>2. CONTENTS</b>	<b>2</b>
<b>3. SPICE ELECTRONIC MODELING</b>	<b>3</b>
<b>3.1 SPICE Software</b>	<b>3</b>
<b>4. SPICE VLF COIL MODELING</b>	<b>3</b>
<b>4.1 Basis of Information</b>	<b>3</b>
<b>4.2 Purpose of SPICE modeling</b>	<b>3</b>
4.2.1 Anomaly Investigation	4
4.2.2 Mismatched Differential Amplifier Resistor Investigation	4
4.2.3 Definitions and Thesis	4
4.2.4 Asymmetrical Capacitance	4
4.2.5 Reverse Polarity Anomaly Thesis	4
<b>4.3 The VLF Coil</b>	<b>4</b>
<b>4.4 Modeling Files</b>	<b>4</b>
<b>4.5 Status of results</b>	<b>5</b>
4.5.1 First Main Result	5
4.5.2 Second Main Result	6
<b>4.6 Work still remaining</b>	<b>6</b>
<b>5. ACKNOWLEDGMENTS</b>	<b>6</b>
<b>6. LICENSING AND DISCLAIMERS</b>	<b>6</b>
<b>7. CONTACT INFORMATION</b>	<b>7</b>

PREVIEW

## 3. SPICE Electronic Modeling

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SPICE is an acronym for "Simulation Program with Integrated Circuit Emphasis." SPICE as a tool has been available since 1973 and has undergone many improvements. SPICE was based on earlier simulators. Within a few years SPICE achieved acceptance at almost all university level engineering schools. A version of the SPICE netlist description language is an industry standard without a standards body.

SPICE circuits are expressed as netlists that are understood by many different software programs, including those with a Windows based schematic capture and editing. Like just about all physical simulators, simulation involves solving a matrix. A software program may use its own matrix solver or one based on a SPICE version itself. Simulation results are now typically expressed in graphical form for different types of simulation analyses.

### 3.1 SPICE Software

The SPICE software used for ZGUS simulations is LTspice. LTspice is available for free use from <http://www.linear.com/designtools/software/switchercad.jsp>.

## 4. SPICE VLF Coil Modeling

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### 4.1 Basis of Information

This information is based on postings <http://tech.groups.yahoo.com/group/zgus/message/41> on 16 January 2008 and <http://tech.groups.yahoo.com/group/zgus/message/42> on 17 January 2008.

These postings declared "Two manufactured capacitor components in the coil housing are sufficient to explain polarity reversal phase anomalies BUT ARE NOT sufficient to explain polarity reversal magnitude anomalies, using SPICE."

### 4.2 Purpose of SPICE modeling

The purpose was to investigate an anomaly and investigate the effects of mismatched amplifier resistors.

## 4.2.1 Anomaly Investigation

During development of SGET technology a curious anomaly surfaced. It is expected reversing the VLF coil polarities of the transmit leads or the receive leads would not affect the amplitude response and would affect the phase response by 180 degrees. The differences that did occur were too large to be attributed to normal experimental conditions and normal expected modeling inaccuracies.

## 4.2.2 Mismatched Differential Amplifier Resistor Investigation

Another purpose of the simulation was to investigate simulations of mismatched differential amplifier results

## 4.2.3 Definitions and Thesis

### 4.2.4 Asymmetrical Capacitance

Asymmetrical capacitance is defined as a lead of a RX coil having a set of possibly two equal capacitance to both leads of the TX side and the other lead of the RX coil having a set of possibly two equal capacitances to both leads of the TX side but both sets are substantially different (or asymmetrical) from each other.

### 4.2.5 Reverse Polarity Anomaly Thesis

Observed mutually coupled coil behavior can be modeled in SPICE by including asymmetrical capacitances between leads.

## 4.3 The VLF Coil

Breaking into the VLF coil housing was required to get appropriate models. The coil is modeled as three electrical coil inductances L1, L2 and L2 with additional physically identifiable capacitors C1 and C2. L1 and L2 are joined in series to from the transmit coil. C1 and C2 are connected in parallel across L1. Coils L2 and L3 overlie each other and this is reflected in the higher mutual inductance assigned by trial (0.001) compared to the other two mutual inductances assigned by trial (0.0001 and 0.0002).

## 4.4 Modeling Files

The models are constructed by assuming a sinusoidal input into into a coil with output from coil going into a differential amplifier. Mismatched differential amplifiers are modeled by parameterising two resistors as {rhigh} and {rlow} with two values each.

There are ten files included in zgus\_spice\_modeling.zip.

Four top hierarchical level .AC simulation analysis schematic files corresponding to the four possible polarity connections. These files are named sget\_vlf\_ac1.asc to sget\_vlf\_ac4.asc

One top hierarchical level .TRAN simulation analysis schematic file to act as a sanity check. This file is named sget\_vlf\_tran\_freq\_sweep.asc. To see the effect of stepping five frequencies it is necessary to change a SPICE comment into a SPICE directive (just right click the SPICE comment on the schematic and change the comment to a directive).

A file representing the VLF coil model, vlfcoil.asc and a symbol file, vlfcoil.asy, enabling the VLF coil to be included as a symbol in the top level hierarchical schematic files.

A SPICE model file representing a TLV2371 opamp, called TLV2371.MOD.

A graphic file, ac\_analysis\_with\_peak\_cursor.png, showing the .AC simulation results at the out1 node with a cursor at the peaks. There are four amplitude and phase plot sets per .AC analysis. Although there appears to be only three, running the simulations and viewing the plots in a large window clearly shows four sets. The four sets correspond to the four possible combinations of resistors of {rhigh} and {rlow}.

A documentation file zgus\_spice\_modeling.pdf (this file).

## 4.5 Status of results

Modeling and analysis is unfinished. Conclusion is conjectured rather than confirmed. The modeling results as compared to the real world were clearly pointing to anomalies reported in forum <http://groups.yahoo.com/group/zgus> as largely attributable to an unexpected coil arrangement, unexpected physical capacitors and to an uneven distributed coil capacitance due to existence of separate internal shielding and its connection to one of the coil leads at the control box. The unexpected physical capacitors on their own cannot explain the amplitude shifts observed.

### 4.5.1 First Main Result

So far nothing has been found to dismiss what has been previously declared in a posting: "Two manufactured capacitor components in the coil housing are sufficient to explain polarity reversal phase anomalies BUT ARE NOT sufficient to explain polarity reversal magnitude anomalies, using SPICE."

## 4.5.2 Second Main Result

The .AC analysis of the four sets of plot clearly demonstrates functionality was retained when differential amplifier input resistors are mismatched.

## 4.6 Work still remaining

The actual real world results need to be included and the conclusions need to be demonstrated as following from comparing simulation results with real world results

A photograph of the broken into coil should be included with identifying labels.

## 5. Acknowledgments

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This work was carried out by John Heenan

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