



ExtraOrdinary Conference **2018**

The “REAL” Tesla Electric Car Motor (Part 2)

Mike Gamble

8/11/18

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1

For those of you that haven't met me, I am Mike Gamble a retired electrical engineer; put in 30 years at (BR&T) Boeing Research and Technology (Seattle, Wa) where I ran an R&D Lab building all kinds of fun stuff. Would like to thank the conference chairman for having me back to talk more about Tesla's work.



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INTRODUCTION

This presentation of “TESLA’S ELECTRIC CAR MOTOR (part 2)” is a continuation of the presentation the “REAL TESLA ELECTRIC CAR MOTOR” from two years ago at the COFE8 conference. Part-1 reverse engineered and confirmed Tesla’s design. Part -2 concentrates on improving the system efficiency with the goal of self resonance.

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2

This presentation of “Tesla’s Electric Car Motor (part 2)” is a continuation of the presentation the “REAL Tesla Electric Car Motor” from two years ago at the COFE8 conference. Part-1 reversed engineered and confirmed Tesla’s design. Part-2 concentrates on improving the system efficiency with the goal of self resonance.



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HISTORICAL REVIEW of Part 1

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3

For those of you that did not see the (Part-1) presentation; will start with a quick review so everyone is on the same page.



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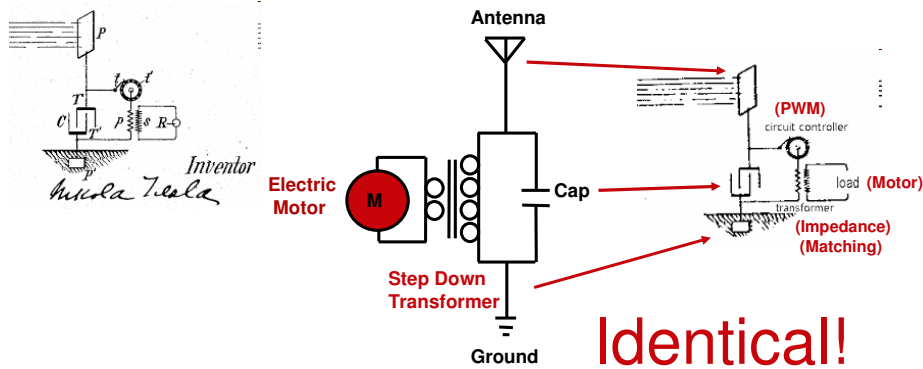
“Electrical power is everywhere present in unlimited quantities and can drive the world’s machinery without the need for coal, oil or gas” – Nikola Tesla, 1892 copyright mg 4

For those of you that haven't heard the stories; It's rumored in books and on the web that Tesla built and drove an electric powered Pierce-Arrow car back in the early 1930s. In (part 1) I started by taking a few of those stories from the web and analyzing them to see if there was any truth in them and to correlate such data to see if it even came close to a "real" motor design. After building and testing a working demo model will state that Tesla's design is VALID!



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Tesla Patent #685,957 (11/5/1901)



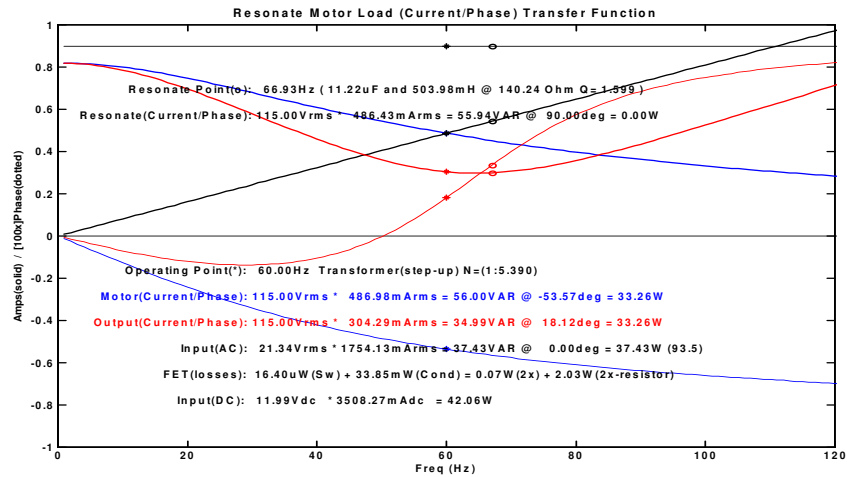
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5

This chart shows the schematics of Tesla's original patented resonate electrical device. The only difference between the reverse engineered one and Tesla's design is nomenclature! The symbols and part names are different (antenna/ground, condenser/capacitor, interrupter/PWM chopper).



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This chart is a MatLab simulation showing the system resonance. Will draw your attention to three things:

- 1) Resonate point and operating point don't line up
- 2) Low "Q" factor [1.6]
- 3) Resonance is supplying only 30% (180mA) of the motor's total current (487mA)



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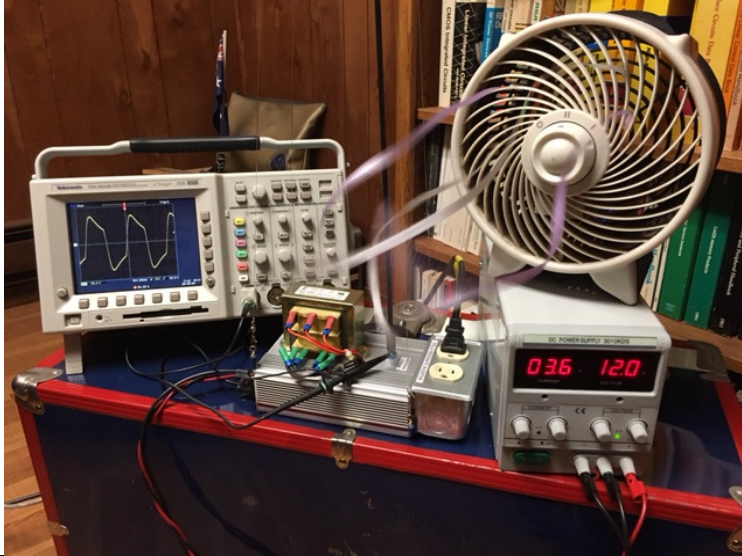
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7

This chart shows different views of the first design resonate demo model running with a 6' whip antenna.



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8

This chart shows a close up view of the running demo model. Note: the AC wave shape and input power readings of 12V @ 3.6A.



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Demo (Fan) Motor Conclusions

- 1) Demo **PROVES** an induction motor can run off a resonate power system
- 2) The (first cut) demo design showed only a small resonate current gain (low $Q= 1.6$)
- 3) which just about equals the inverter (losses) inefficiencies (89% circuit, 93% transformer)
- 4) Not enough resonate gain (Q) to achieve “standalone” operation
- 5) Need an inductor with a higher Q factor ($Q= 5-10$) and
- 6) Need a better tuned antenna (loading)
- 7) However, the demo **PROVES** Tesla’s resonate design was **VALID** (real) he did not break any electrical rules (no black boxes or black magic)!
- 8) Based on this research, my engineering experience, a working demo model and the many rumored accounts; would have to conclude Tesla **“ACTUALLY”** built and drove an electric powered Pierce-Arrow! 9

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Part 2 Resonate System Design Modifications “Real Engineering”

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10

Part 2 starts the “real engineering” of improving the resonate power system.



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DESIGN GOALS

- 1) Increase the resonate system “Q” factor using two different methods
- 2) Increase the resonate operating voltage
- 3) Improved the resonate antenna design
- 4) Changed the PWM chopper circuit from voltage mode to current mode operation
- 5) Decrease the input power

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11

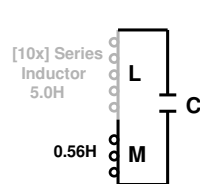
Part-2 Design Goals:

- 1) Increase system “Q” factor using two different methods
- 2) Increase the resonate operating voltage
- 3) Improved the resonate antenna design
- 4) Changed the PWM chopper circuit from voltage mode to current mode operation
- 5) Decreased the input power

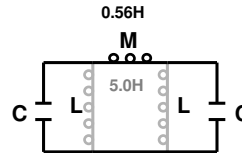


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- 1) TWO (2) WAYS TO INCREASE THE RESONANCE “Q”
- a) Add a bigger [10x] inductor in series with the load (motor)
 - b) Move the load (motor) out of the resonate circuit



a) Series Inductor



b) Dual Resonators

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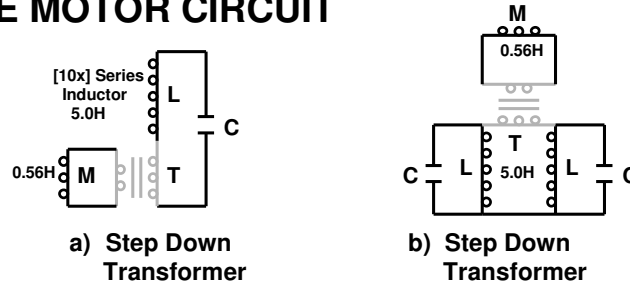
12

DESIGN GOAL 1: This chart shows two different ways to increase the “Q” factor of a resonance system. Figure “a” adds a large (10x) inductor in series with the load (motor). This increases the reactive component without significantly increasing the real one. Figure “b” moves the load (motor) out of the resonate circuit. This reduces the real component without significantly reducing the reactive one. The motor current now becomes the input current of both the dual resonate circuits.



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2) INCREASE THE RESONATE VOLTAGE BY ADDING A STEP DOWN TRANSFORMER TO THE MOTOR CIRCUIT



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13

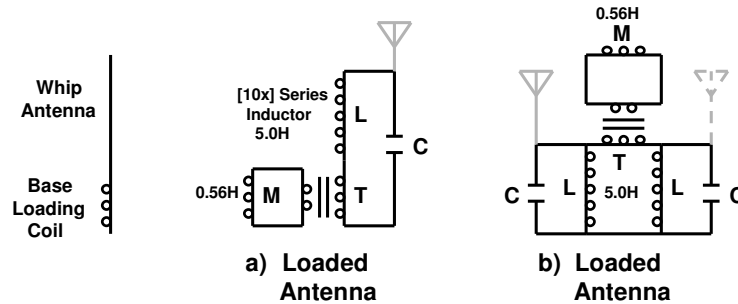
DESIGN GOAL 2: This chart shows one method of increasing the resonate voltage by placing a stepdown transformer between the load (motor) and the resonate circuit. Figure "a" shows the series inductor implementation and figure "b" shows the dual resonate implementation.



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3) TWO WAYS TO INCREASE ANTENNA EFFICIENCY:

- a) Higher operating voltage (goal 2)
- b) Loaded coil antenna



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14

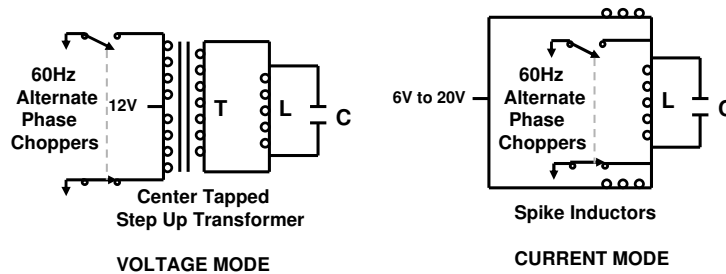
DESIGN GOAL 3: This chart shows one method of increasing the antenna efficiency. First, by increasing the system's operating voltage (goal 2) which gives the antenna a larger field pattern. Second, using a loaded coil antenna to more closely match the resonate system's impedance. The dual resonate system may need only one antenna as the resonate circuits are mirror images.



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4,5) CHANGE VOLTAGE MODE TO CURRENT MODE OPERATION:

- a) Eliminates big HV transformer
- b) Easier to change input voltages



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15

DESIGN GOALS 4, 5: This chart shows one method of changing the system's input from a voltage source to a current source. The benefits include the following:

- 1) Simpler method which uses smaller/less components.
- 2) Eliminates the big heavy HV/fixed voltage transformer.
- 3) Current mode can operate from various input voltages.



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FIRST METHOD: ADD LARGE SERIES INDUCTOR [Design Data]

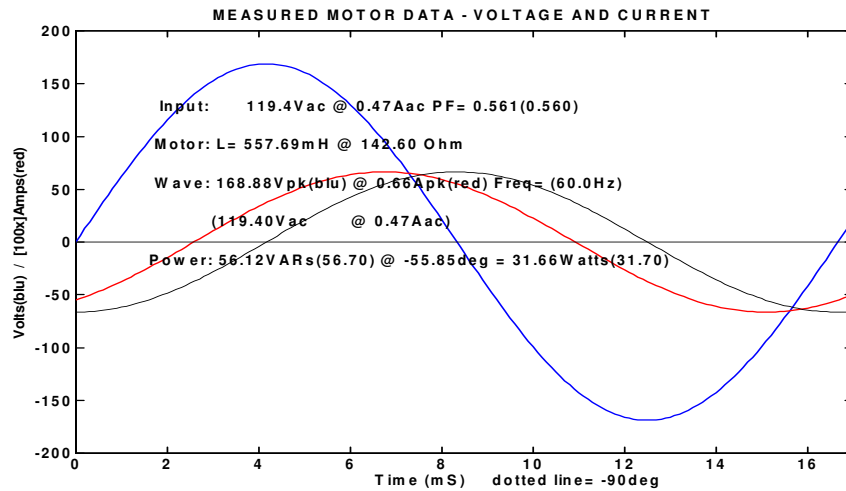
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This chart starts the detailed design of the first “A” method that of using a larger [10x] series inductor.



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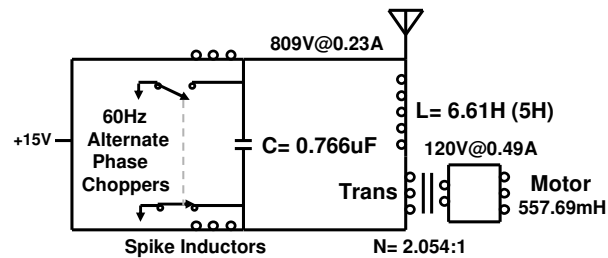
17

This chart show the MatLab calculations for the motor load impedance (Z_m) and phase angle given the measured input voltage and current values. Also, shown is the theoretical 90deg phase curve where it must to operate for resonance; the closer to 90deg the better.



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SERIES INDUCTOR PROPOSED CIRCUIT BLOCK DIAGRAM



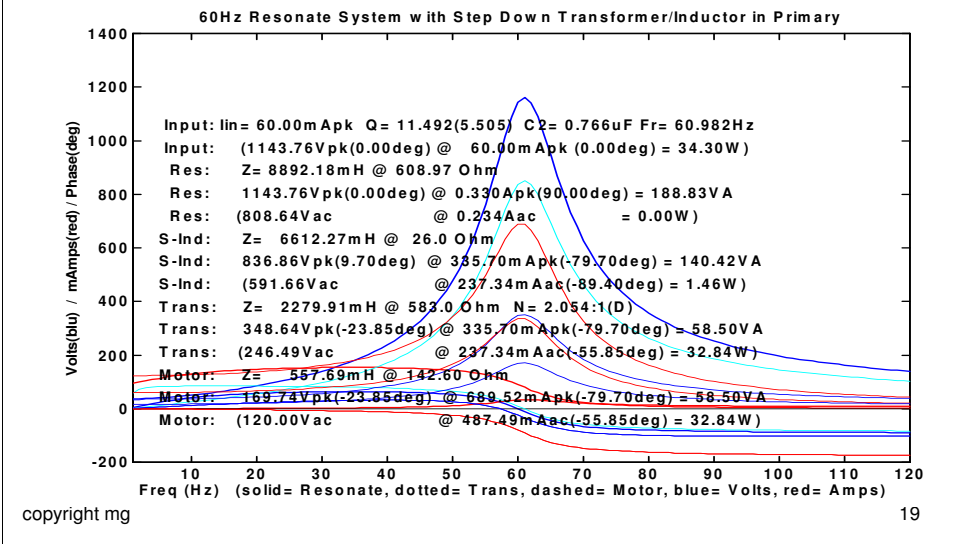
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18

This chart shows the block diagram of the proposed series resonant circuit using a 2.054:1 stepdown transformer with a 5H inductor. Note: The actual working inductance is measured to be 6.6H as fixed inductors change value with a change in current; less current = higher inductance.



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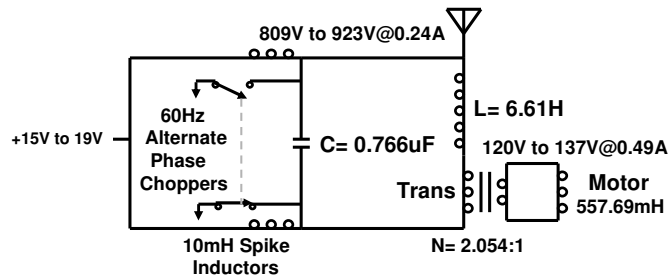


This chart shows the MatLab simulation of the resonate system showing the contribution of each component (motor, transformer, series inductor, input). The resonate freq (60.98Hz) is set higher than the (60Hz) operating freq to keep the phase angle at zero (0) degrees. Note: the resonate “Q” of 5.5 is doubled to 11.5 by the stepdown transformer’s turns ratio.



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SERIES INDUCTOR “RUNNING” SYSTEM BLOCK DIAGRAM MODs - Increased Input Voltage



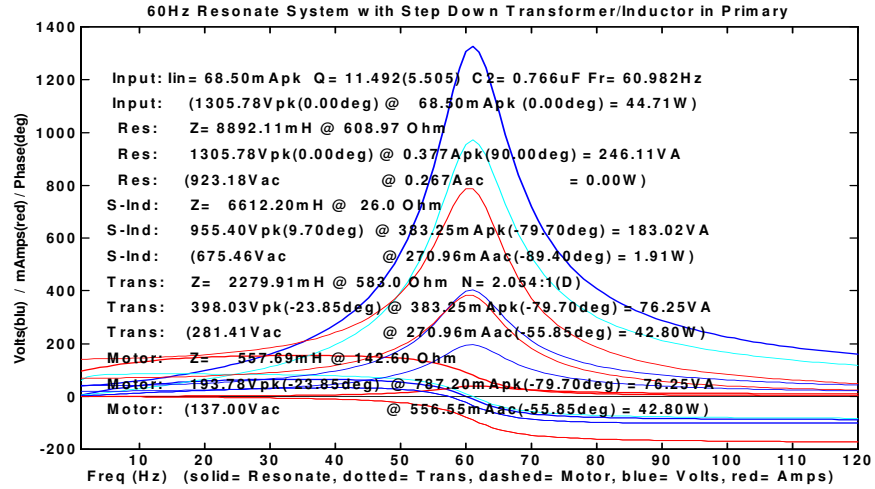
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20

This chart shows the block diagram of the “running” series inductor resonate system. Upon building and running the circuit it required an increased input voltage of 19Vdc to get the correct AC motor operation. This was higher than the calculated 15Vdc input as the output resonate wave shape is not a perfect 120V sine wave and chopper power losses.



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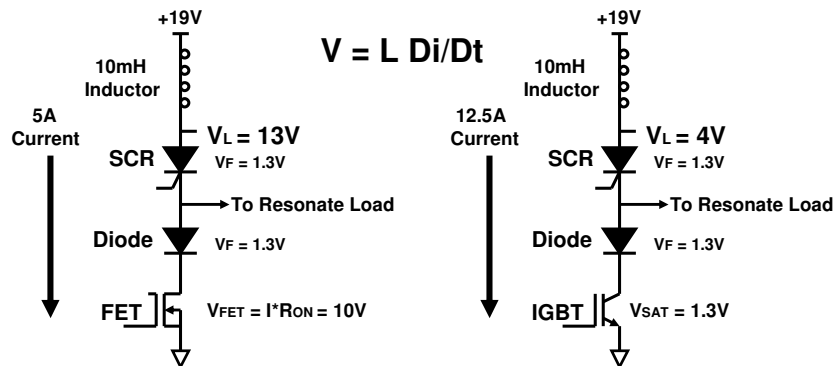
21

This chart is the MatLab simulation of the re-calculated 26% increase of the input voltage required to get the correct 137Vac(120) motor operation due to the imperfect sine wave reproduction and power losses.



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PROBLEM: FET "Ron" Resistance



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This chart shows one of the many electrical R&D engineering component problems that had to be solved to get the system running. It summarizes the high voltage FET "Ron" problem. When charging a high current inductor using a high voltage FET, the "Ron" decreased the inductor charging voltage ($6V = 19V - 13V$). By replacing the high voltage FET with a high voltage IGBT the inductor charging voltage was increased ($15V = 19V - 4V$).



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PWM CHOPPER SCHEMATICS

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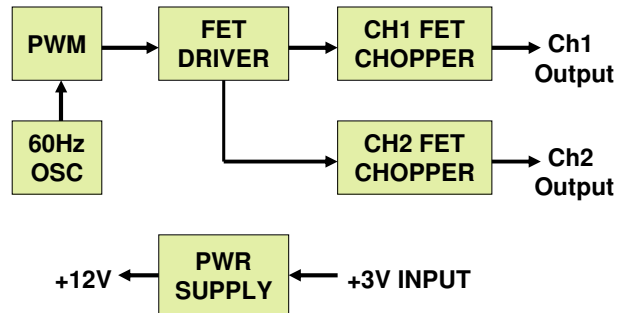
23

The following charts show the detailed schematics of the “Series Inductor Resonate” system and PWM Chopper circuit.



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SERIES RESONATOR CONTROLLER BLOCK DIAGRAM



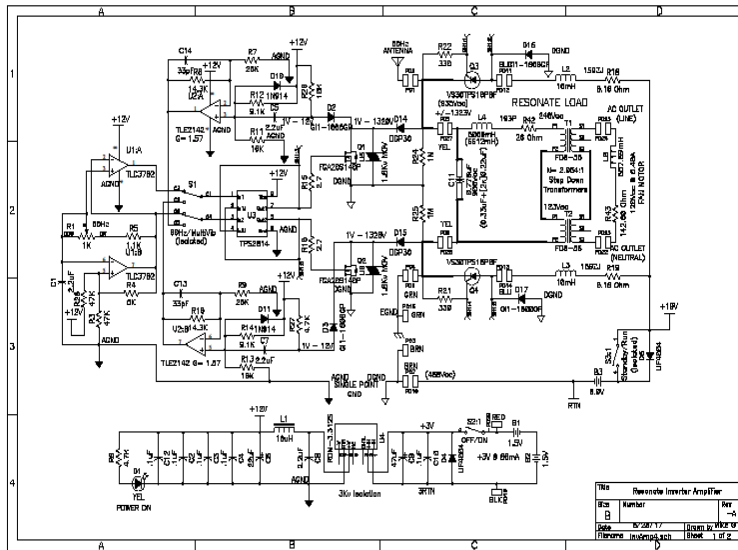
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24

This chart shows the block diagram of the “series inductor” resonate system controller.



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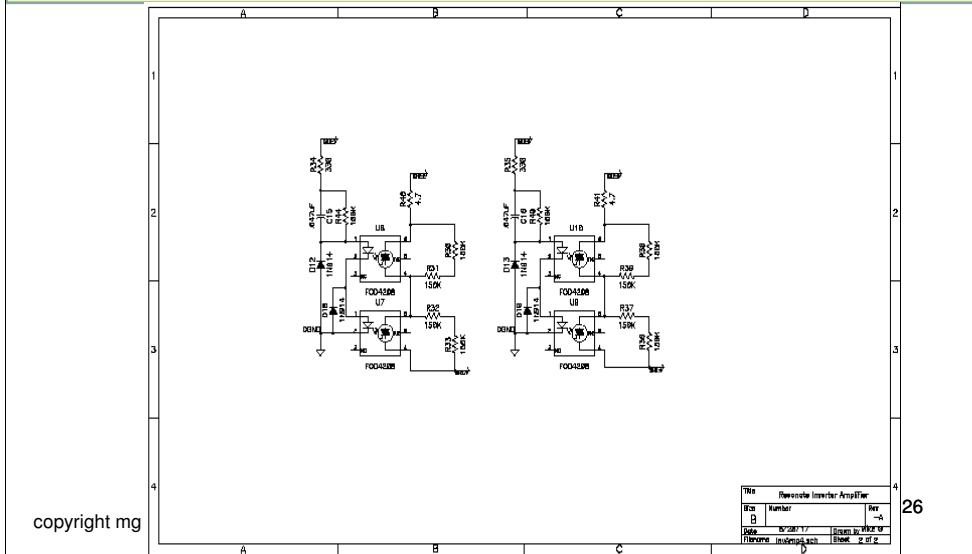
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25

This chart shows the actual schematics (page 1) of the “series inductor resonate” system and PWM chopper circuit.



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This chart shows the actual schematics (page 2) giving the details of SCR driver/isolators



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O-SCOPE MEASURED DATA [Series Inductor]

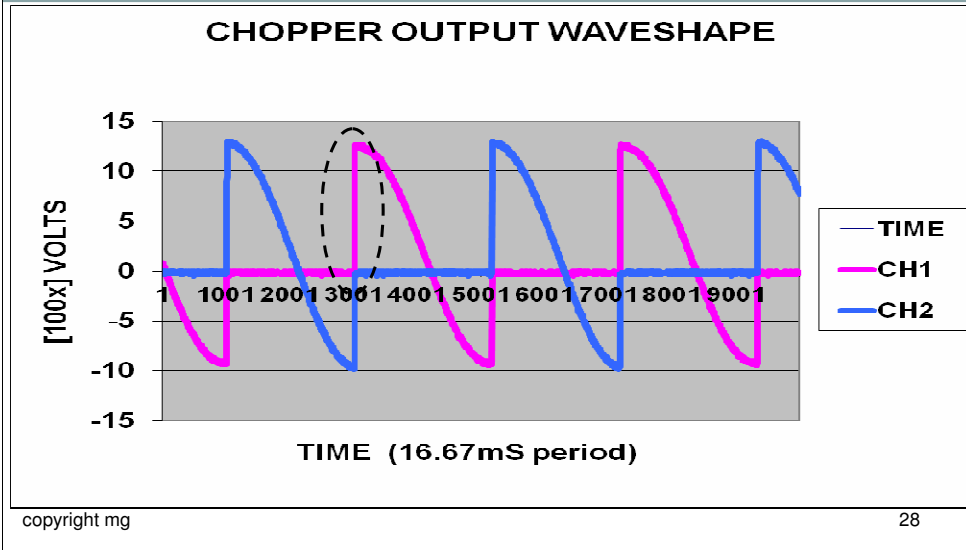
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27

The following charts are actual O-Scope measured data from the running series resonate system.



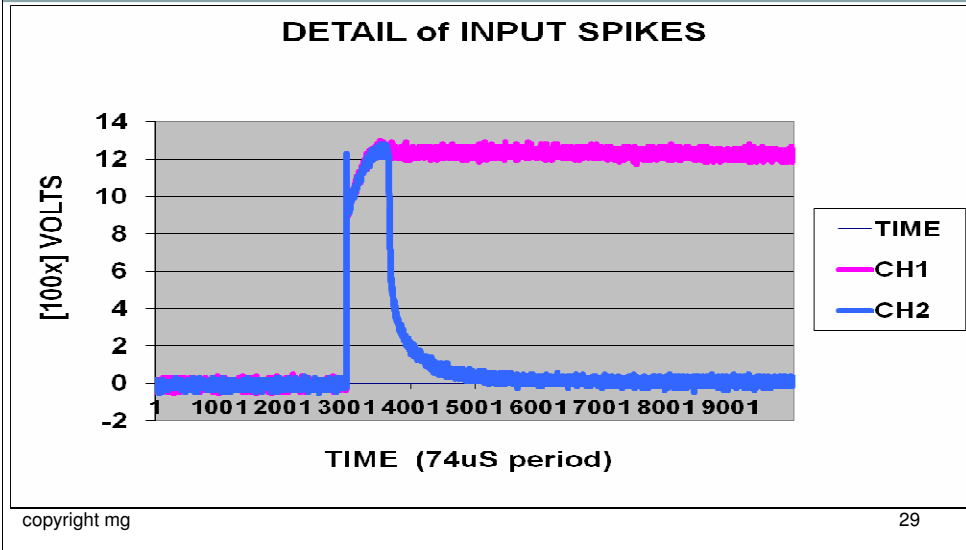
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This chart shows the output wave shape of the dual 60Hz chopper circuits running a 180 degrees out of phase. The peak operating voltages are +1.35Kv and -1.0Kv. However, this chart does not look very much like a normal AC sine wave. The next chart shows the details of the highlighted “oval” area.



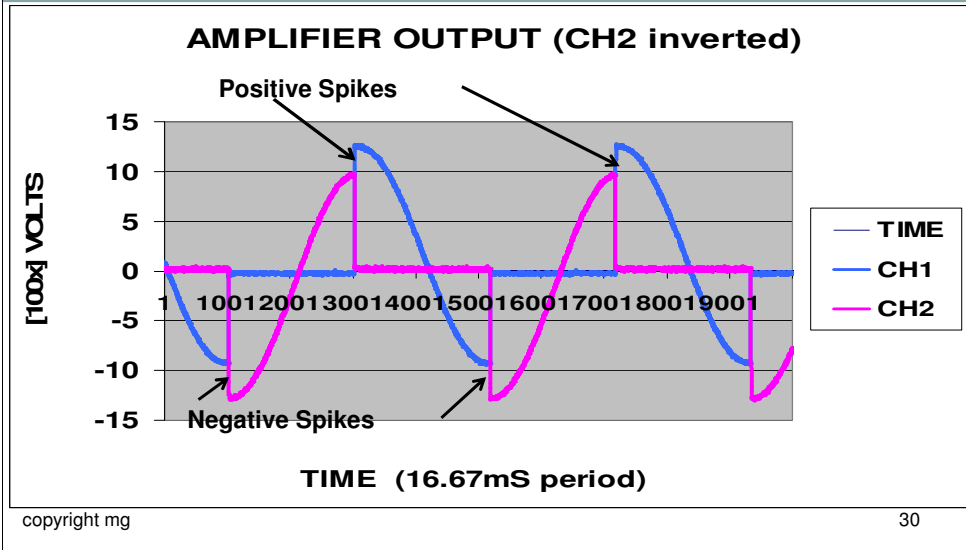
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This chart (oval area) gives a more detailed look at the input voltage spikes at the start of each segment of the AC resonate sine wave. CH1(pnk) shows a greatly expanded view of the start of one segment of the sine wave and CH2(blu) shows the 74uS 1.35Kv driver spike pulse that starts each resonate wave segment.



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This chart shows the output 60Hz AC resonate sine wave more clearly by inverting scope CH2. However, the wave not a perfectly symmetrical sine wave because of the +/-350V voltage spikes. The 350V losses represent the power used in running the motor.



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PICTURES OF THE SERIES RESONATE INVERTER DEMO MODEL

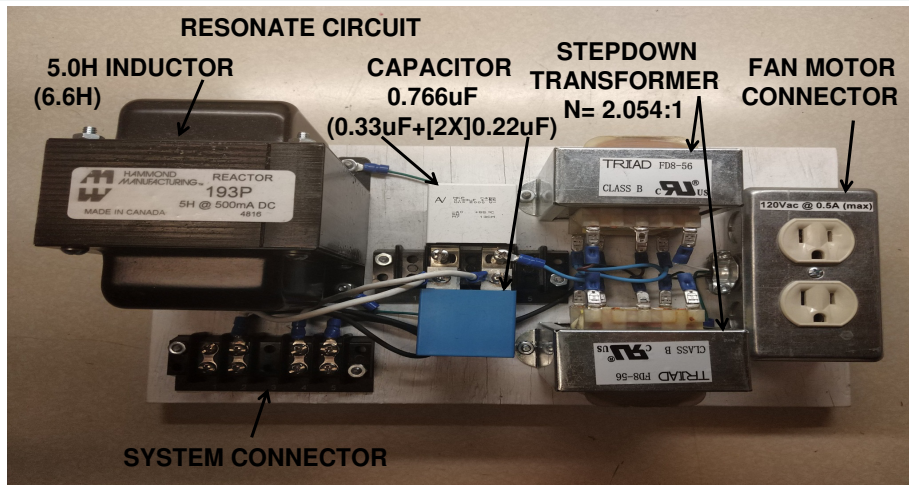
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31

The following charts show the detailed pictures of the actual “Series Resonate Inverter” demo model.



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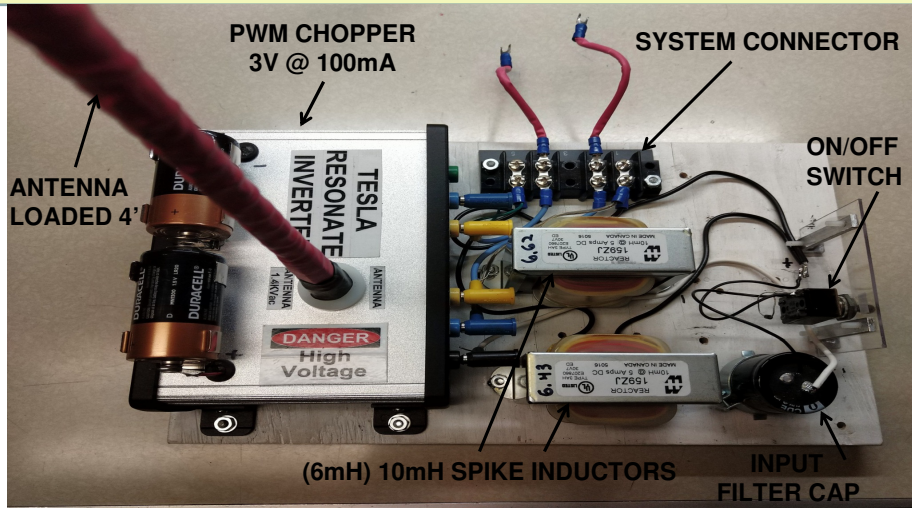
RESONATE CIRCUIT BOARD

32

This chart shows a close-up of the resonate circuit board of the series inductor resonate system.



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SPIKE INDUCTOR BOARD

33

This chart shows a close-up of the spike inductor board of the series inductor resonate system.



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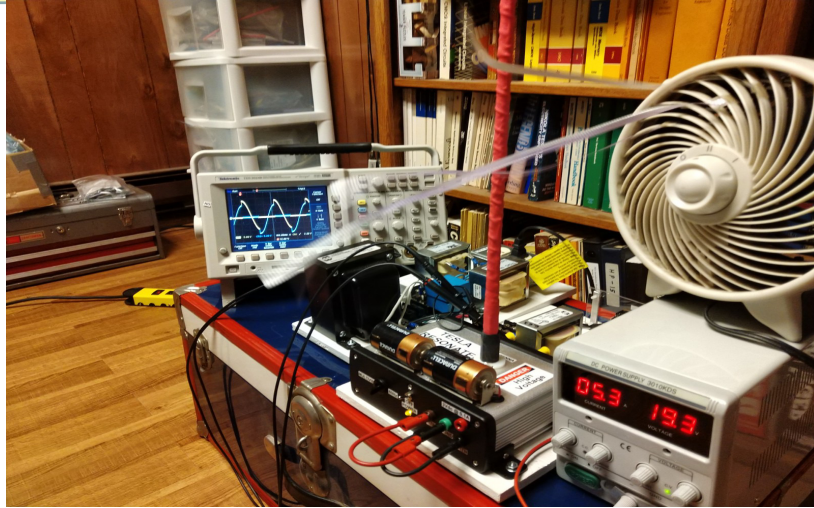
Left and Right Views of the Running Demo Model

34

This chart shows different views of the “Series Inductor Resonate” system demo model running with a 4’ whip antenna.



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Close-Up View of the Running Demo Model

35

This chart shows a close up view of the running demo model. Note: the spiked AC wave shape and input power reading of 19.3V @ 5.3A.



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Series Inductor Test Results

- 1) Only achieved a “Q” factor of 10.12, that’s a 12% decrease from the calculated 11.49 value due to the non symmetrical AC resonate sine wave
- 2) However, the motor current is 92% resonate current and only 8% input current
- 3) Changed choppers from FETs to IGBTs because of “Ron” resistance problems (Ron VS Vsat losses)
- 4) Had to increase the input voltage 26% (15V-19V) to cover system losses

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36

This chart shows the test results of the series inductor method:

- 1) Only achieved a “Q” factor of 10.12, that’s a 12% decrease from the calculated 11.49 value due to the non symmetrical AC resonate sine wave
- 2) However, the motor current is 92% resonate current and only 8% input current
- 3) Changed choppers from FETs to IGBTs because of “Ron” resistance problems (Ron VS Vsat losses)
- 4) Had to increase the input voltage 26% (15V-19V) to cover system losses



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SECOND METHOD: DUAL INDUCTOR RESONATE SYSTEM [Design Data]

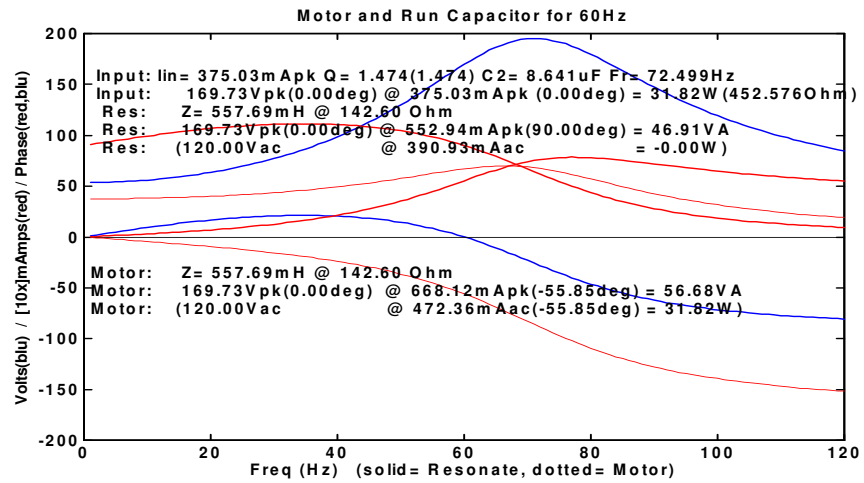
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37

This chart starts the detailed design of the second “B” method that of using a dual inductor resonate system.



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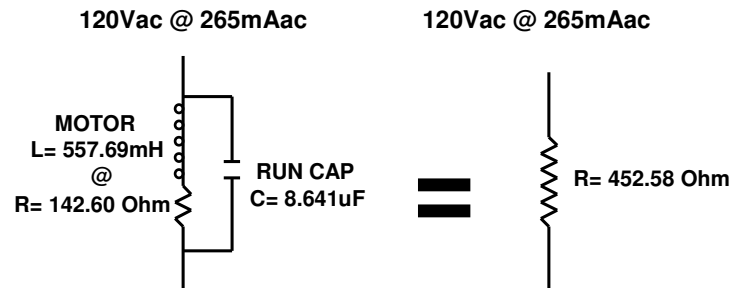
38

This chart is the MatLab calculations for the motor and run (shunt) capacitor. The simulation shows that the resonate motor/cap circuit equals the impedance of a fixed resistor at 60Hz – zero phase angle. Note: the resonate freq (72.5Hz) is much higher then the operating freq (60Hz) because of the low “Q factor”.



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SHUNTING THE MOTOR WITH A 8.641uF CAP PULLS THE PHASE BACK TO ZERO (60Hz)



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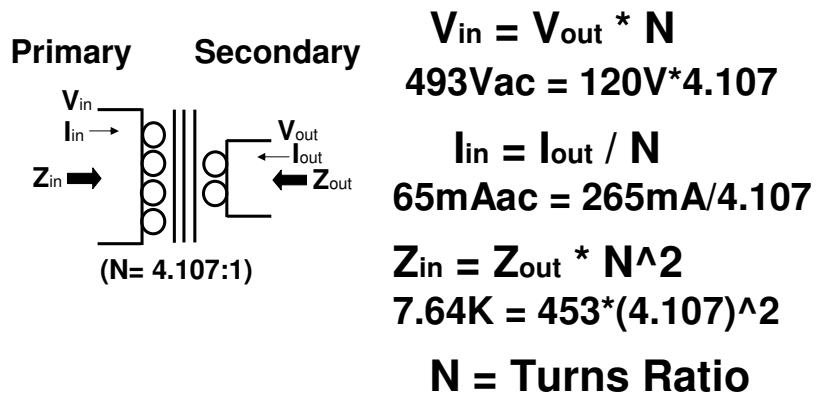
39

This chart shows a block diagram of the motor and shunt (run) capacitor operating at 60Hz is equivalent to a fixed resistor with zero phase angle. The dual inductor resonate system has a resistive load requirement; any phase shifting will decrease the resonances.



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Step Down Transformer



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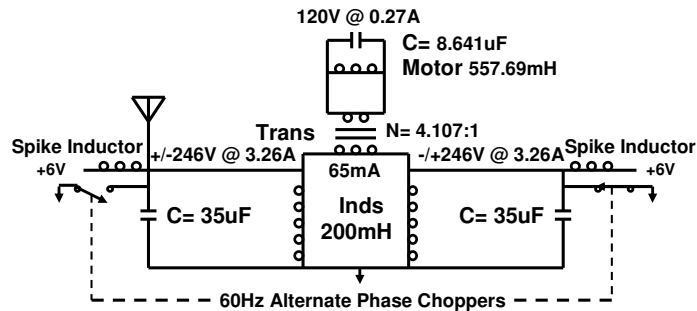
40

This charts show the 493Vac @ 65mAac transformer (4.107:1) input needed to run the motor/cap system @ 60Hz.



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DUAL RESONATE INDUCTORS BLOCK DIAGRAM



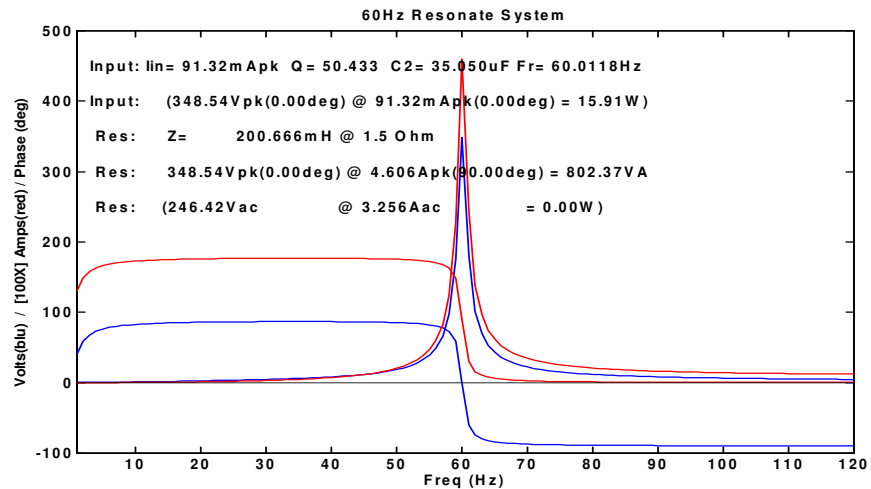
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41

This chart shows the block diagram of the proposed dual resonate inductor system using the 4.107:1 stepdown transformer. Each of the dual resonator circuits only has to supply half this voltage (246Vac @ 65mA) because the load is shared differentially. Note: The resonate voltage is reduced while the resonate current is increased as compared to the series inductor method "A".



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This chart shows the MatLab simulation for one of the resonate circuits of the dual resonate system. As you can see it has a “Q factor” of 50 with very sharp resonate peaks. Removing the motor’s real impedance from the resonate circuit greatly increased the “Q” factor; the input current (91.32mA) is only 2% of the resonate current (4.61A). However, 200mH @ 5A inductors are very big and heavy; a standard value part is 100mH @ 5A; so four units would be required. Therefore, would recommend replacing the actual physical inductors with gyrators (simulated inductors). Also, 35uF high current capacitors are a bit on the large size.

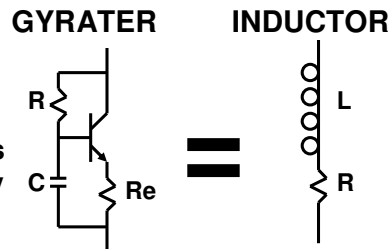


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BLOCK DIAGRAM OF A GYRATER CIRCUIT

ADVANTAGES

- 1) No big chunk of iron
- 2) Can simulate non standard inductor values
- 3) Inductance does not vary with the current



A GYRATOR IS AN "RC" CIRCUIT WITH IT'S OUTPUT INVERTED (180deg) AND IS EQUIVALENT TO AN INDUCTOR'S "LR" IMPEDANCE.

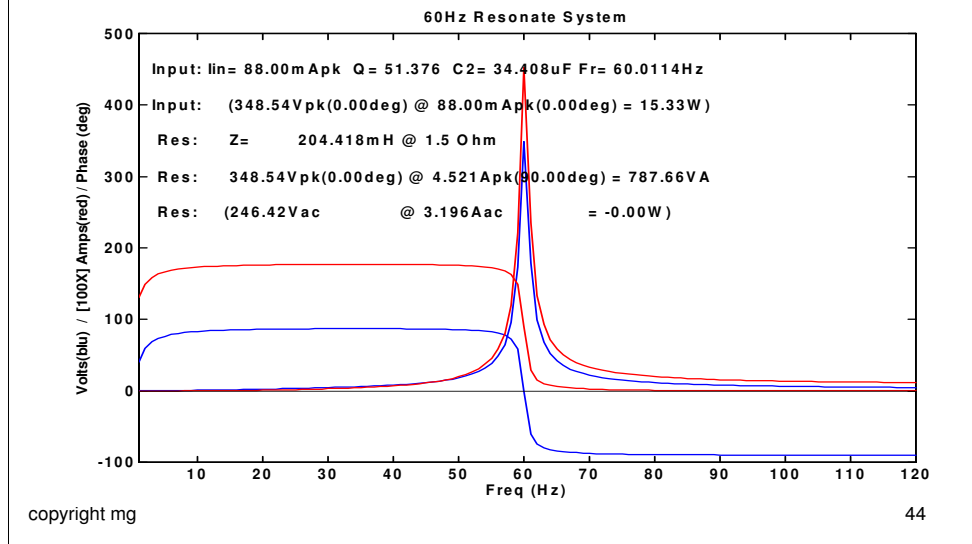
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43

This chart shows a block diagram of a gyrator circuit which is equivalent to an inductor. By inverting a capacitor's +90deg phase by 180deg it simulates the -90deg phase of an inductor. Also, this circuit has some advantages over "real" fixed inductors (size, weight, cost).



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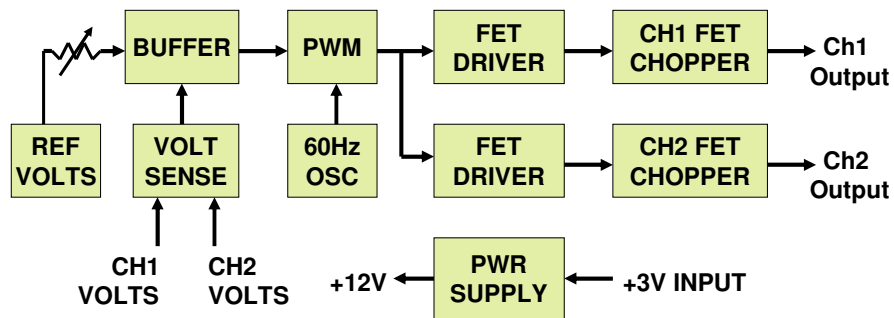


This chart shows the MatLab calculations for a (modified) reduced input current (91mA to 88mA) resonator design which should achieve self resonance. By increasing the inductance “L” a little (200mH/204mH) and decreasing the capacitance “C” a little (35uF/34uF) the circuit can be re-tuned. In theory if the motor cycles 91mA between the two resonators and they only require an input of 88mA the voltage per cycle should start to increase (ratchet up).



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DUAL RESONATOR CONTROLLER BLOCK DIAGRAM



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45

This chart shows the proposed block diagram of the dual inductor resonate system controller.



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This is a crude block diagram of the Tesla device.... it's all I can remember these days so it is lacking important details that can be duplicated by an enterprising garage inventor. The main thing is that Tesla used a transmitter and not a receiver... his transmitter resembled a **Super Heterodyne system**; but, the difference is that each 6 tube assembly of the 12 tube total system [if that is really accurate] is for each 12"x12"x6" **reactive cavity** [2'x12"x6" total cabinet dimension making two 12"x12"x6" enclosures that need a **tuning rod that is 3" tall to tune a 6" deep cavity!**] and the propose of them is to provide a 50-100hz boosted oscillations [from the battery power through the tubes] into the mast antenna inductive coil. The invitation excitation comes from the frame reference which is biased to the other 2 phase motor tap. NOTE: the **motor has to be started via a standard electric automotive engine starter** that initially props over the system. All of these functions should be easily reproduced by frequency generators and amplifiers.

When **system is in phase the motor will spool up** until it explodes or melts down. Controlling it [taking them out of phase] is to take one system out of phase via a variable resistor [making it the throttle]. The beauty of this system is that it will always **need constant throttle corrections**; but, used in automotive applications that is done automatically, unconsciously by the operator/driver.

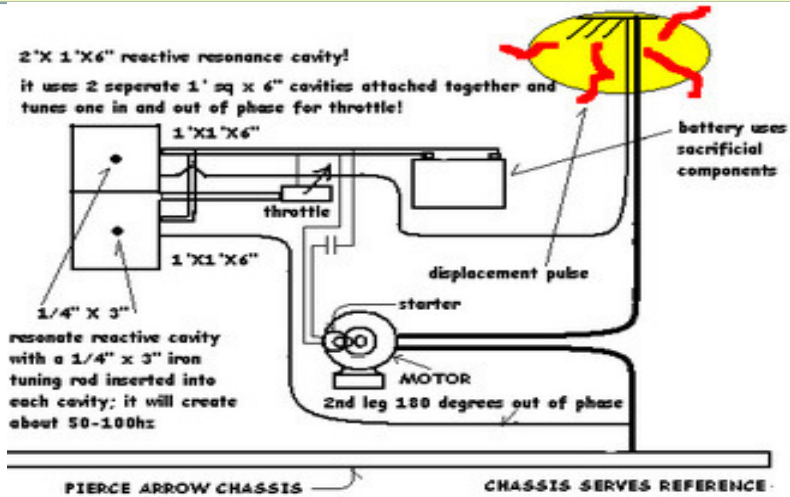
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46

In addition to the four original Tesla Car stories I got off the web and analyzed in the (part 1) presentation, I found this fifth "Tesla Car" story that gives a more technical overview and also includes a detailed block diagram. Used the same "red" highlighting method for any relevant technical specs as per the first four stories.



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This Tesla Car story's block diagram is very similar the proposed dual inductor resonate system. As you can see it also has the motor connected between the two resonators with only one antenna and a car battery. The only difference is that it's direct drive using no step down transformer.



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Resonate System Conclusions

- 1) The “Dual Inductor Resonate” system has been mostly designed
- 2) However, the “Dual Inductor Resonate” system has yet to be built and tested; most of my time this year was spent working on the “Series Inductor” resonate system presentation
- 3) A working “Dual Inductor Resonate” system demo model would make a good “Part 3” for next year’s conference (any interest)?

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48

Dual Inductor Resonate System Conclusions:

- 1) The “Dual Inductor Resonate” system has been mostly designed
- 2) However, the “Dual Inductor Resonate” system has yet to be built and tested; most of my time this year was spent working on the “Series Inductor Resonate” system presentation
- 3) A working “Dual Inductor Resonate” system demo model would make a good “Part 3” for next year’s conference if anyone is interested?



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THANK YOU

CONTACT INFO

Mike Gamble (Boeing Retired)

mike.gamble.retired@gmail.com

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49

Thank you for watching my reverse engineered presentation on "Tesla's Electric Car Motor". Any questions? Contact information



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50