Proposed High-Voltage High-Current Solid State Tesla Coil Spark Gap Design

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Revision 1

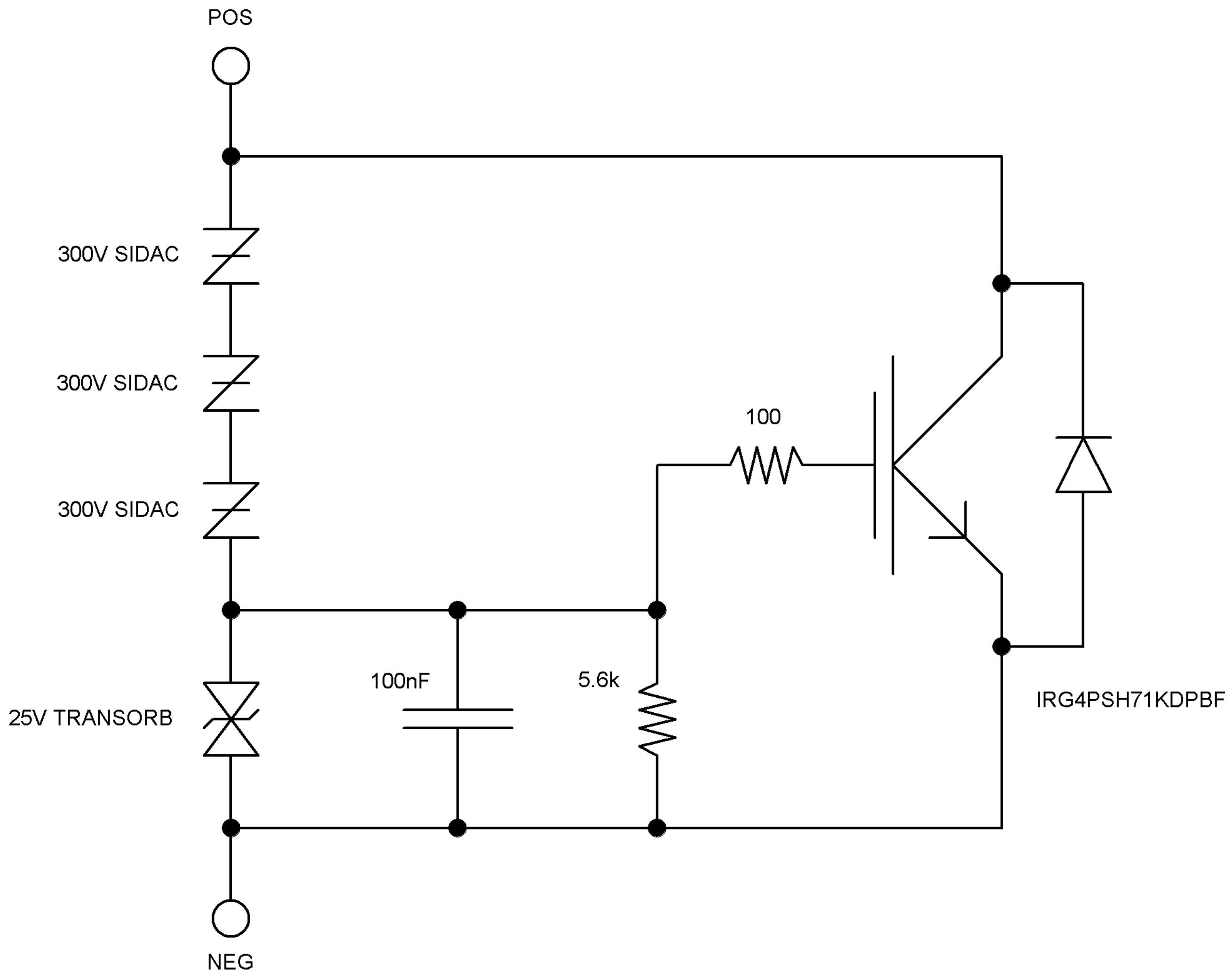
With the invention of the OLTC, DRSSTC and some other IGBT based Tesla coils, it is apparent that IGBTs can be run in the range of currents necessary for Tesla coil primary circuit use. However, the maximum voltage for common (cheap) IGBTs is currently limited to 1200V which is too low of voltage for use in normal disruptive type Tesla coils.

What is proposed is a method of putting IGBTs sections in series to increase the voltage as needed. Each section is self contained with firing and timing circuits built in. Thus, the sections can simply be stacked in series for any firing voltage desired. Operation is then very similar to a conventional spark gap.

Since the circuit is polarized, the output for the high voltage transformer needs to be rectified. That is fairly simple with arrays of inexpensive rectifiers such as the 1N4007.

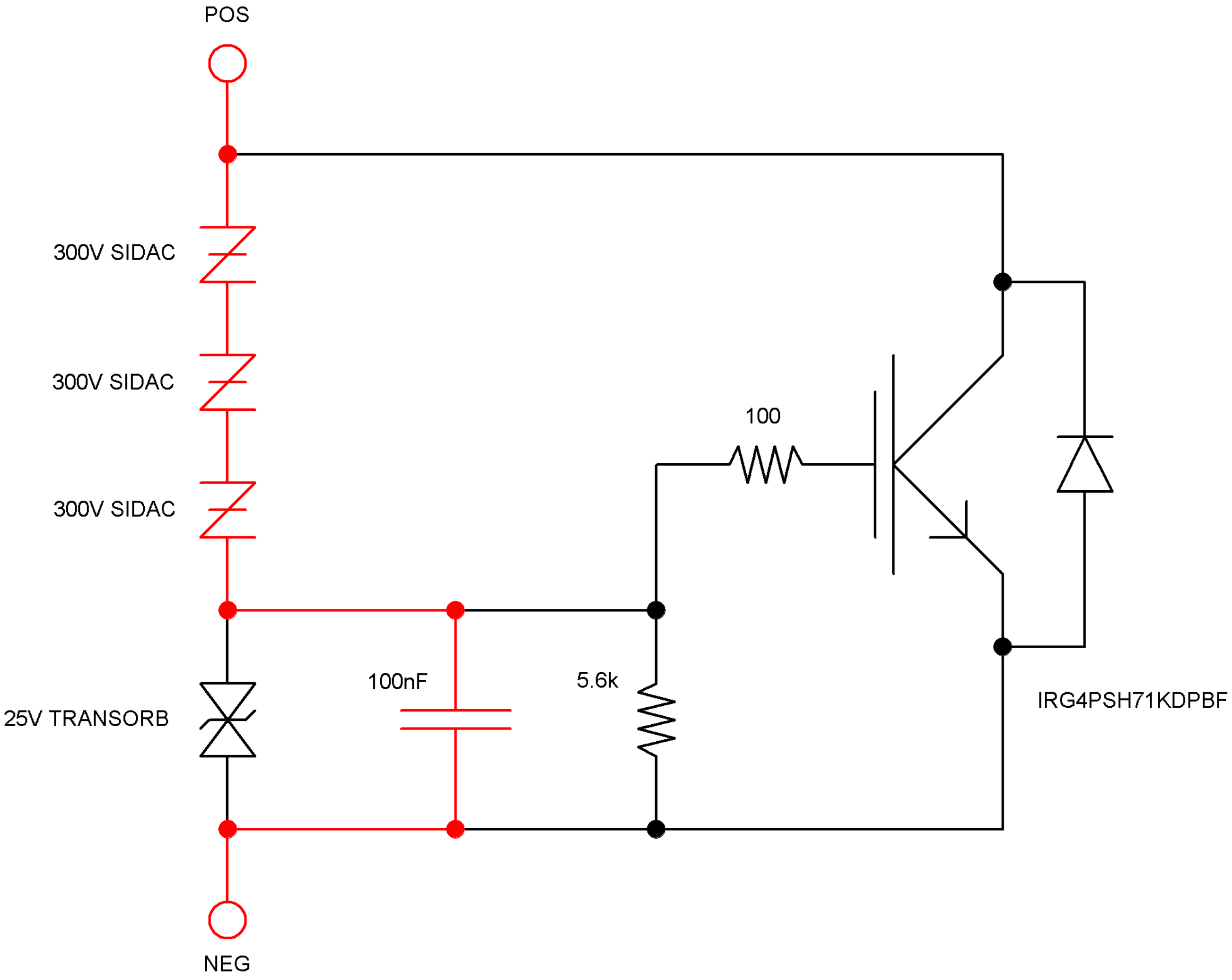
What follows is the operation of one such proposed design.

NOTE!
These circuits are untested and a preliminary concept only!



This circuit is composed of three 300 volt SIDACs in series set to fire at about 900 volts. There is a common 25V bi-directional transorb, capacitor, resistors, and a 1200V IGBT.

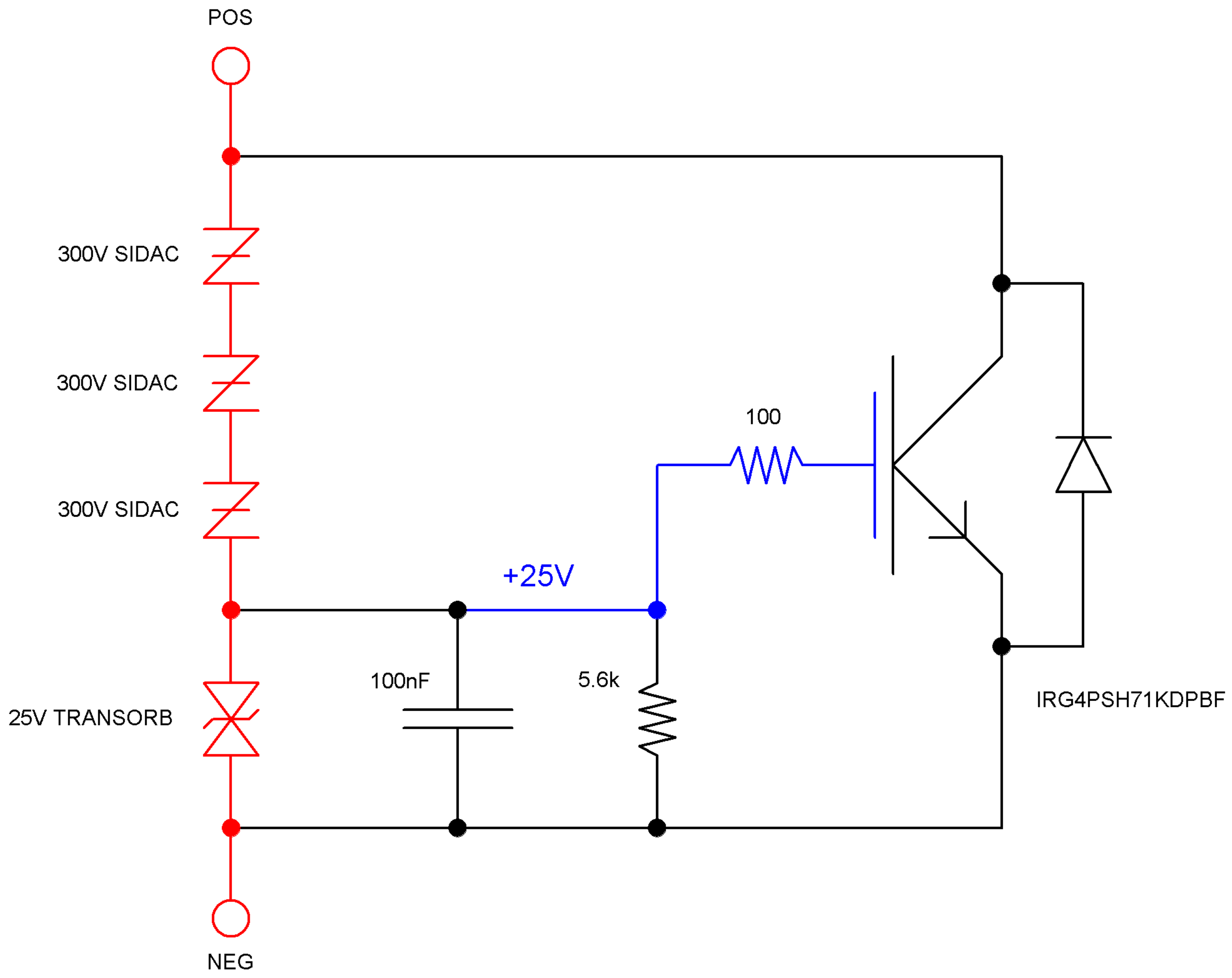
As the voltage across the system increases, there is no current flow until the SIDACs fire at about 900V.



Once the SIDACs fire, the initial primary current flows in the path shown in red. If we assume a 250kHz primary system with a peak current of 400 amps (a fairly stressful case), the current will increase at a rate of 400A/uS, although, the SIDACs "theoretically" limit the current increase to 150A/uS. If we assume the current is 250A/uS, we can find the time it takes to charge the capacitor to 25 volts.

$V = 1/C \int i(t)\, dt$ ==> $25 = 1 / 100E{-}9 \times 250E6\ T^2 / 2$ T == 141nS

So the capacitor reaches a 25V charge in roughly 150nS.

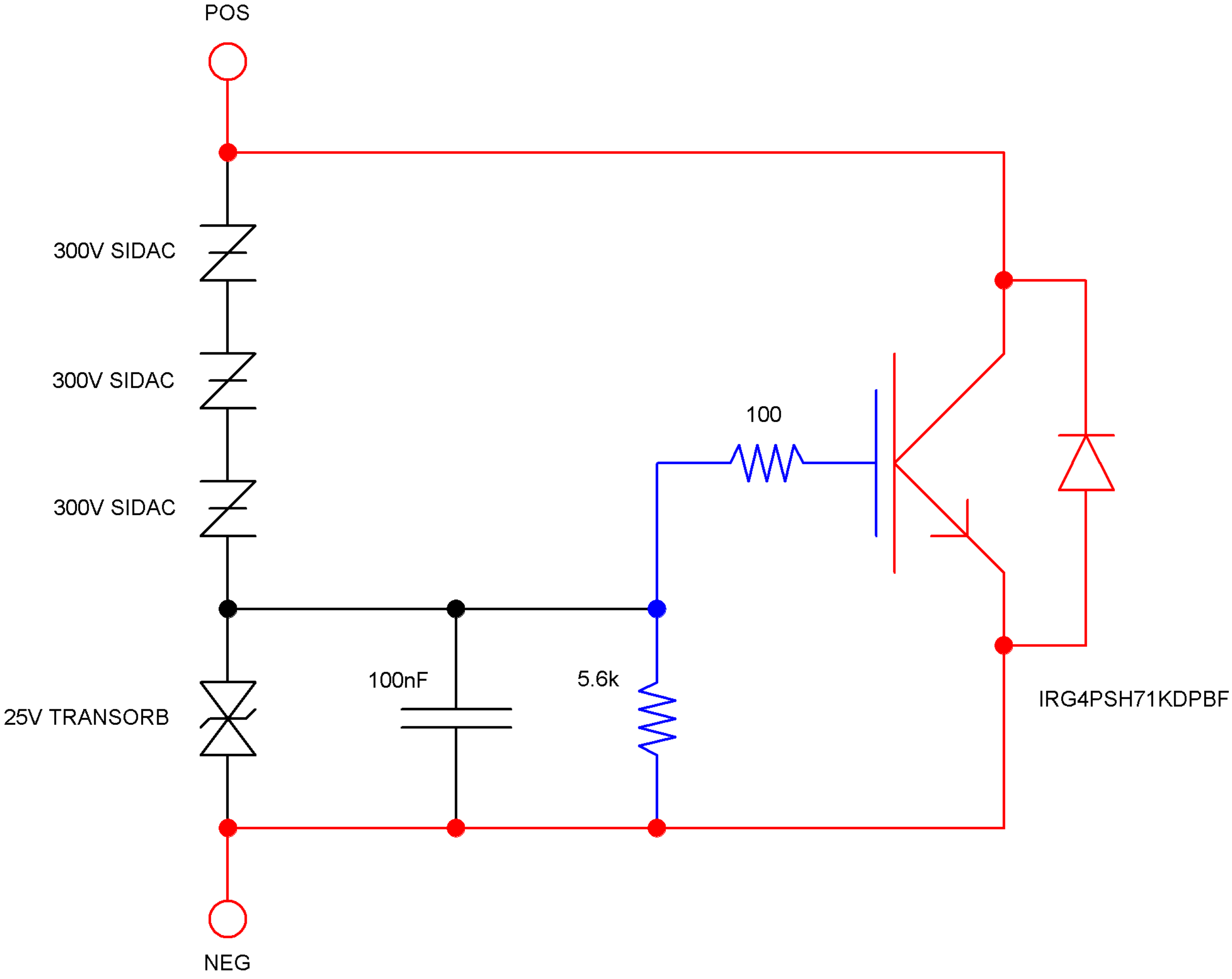


When the capacitor reaches 25V, the transorb takes over the main current load as shown in red. This string is rated at roughly 100 amps which "hopefully" gives time to turn on the IGBT to take over the full circuit current load (250nS).

The IGBT shown has in input capacitance of 5.77nF. and it begins charging with the capacitor but slower due to the 100 ohm resistor. The resistor slows the IGBT turn on so the capacitor can charge to full voltage. If we assume the IGBT begins to turn on hard (100 amps) at 9 volts, we can find the time it takes for the IGBT to take over the load current.

Vg = Vo (1-e^(-T/RC)) ==> 9 = 25 (1 - e^(-T / (100 x 5.77E-9)) T = 257nS (just in time ;-))

The resistor value can be changed as needed.



Once the load is taken over by the IGBT, the circuit is set to run as a full shorted gap (red path). The IGBT will pass current in one direction and the anti-parallel diode will pass current in opposite direction. With the voltage across the SIDACs removed, they will eventually turn off and return to the pre-fire state. With no current flow into the capacitor and no current drain path other than the 5.6k resistor, the IGBT will stay in conduction until the gate voltage drops to about 4 volts. The time is as follows.

$V = V_o \times e^{(-T/RC)}$ ==> $4 = 25 \times e^{(-T / (5600 \times 105.77E-9))}$ $T = 1.06\text{mS}$

Thus, the gap will stay in conduction long after the primary current dissipates but well before the next firing cycle. This resistor value can also be changed at will.

We can vary roughly estimate the power dissipation. If we assume 25 cycles per bang with an average current of 100 amps at 120 BPS and a collector to emitter voltage of 4 volts. then the power dissipation is as follows.

(100 x 4) x 25 / 250000 x 120 = 4.8 watts

If a system fires at 20000 volts and requires 22 sections, we will loose 107 watts to the electronic spark gap proposed. Since that is spread of 22 IGBTs it is easily in range of very low air flow cooling.

If a 15/60 NST system presently uses 900 watts of power (of which 300 watts is lost to spark gap heat) and puts out 50 inch arcs, this system should supply the coil with 193 extra watts of power. If we recompute the Freau coefficient:

L = F SQRT(power) ==> 50 = F SQRT(600) F=2.04

Now if we add the extra power:

2.04 x SQRT(600 + 193) = 57.48 inches or a 15% increase in arc length.

The cost of a 22 section system can be estimated assuming the capacitors, resistors, and transorbs are in the $30 total range. 66 x 300V SIDACS (K3000F1-ND) run $17 and 22 x IGBTS (IRG4PSH71KDPBF-ND) run $266. So the total cost is in the $310 range.