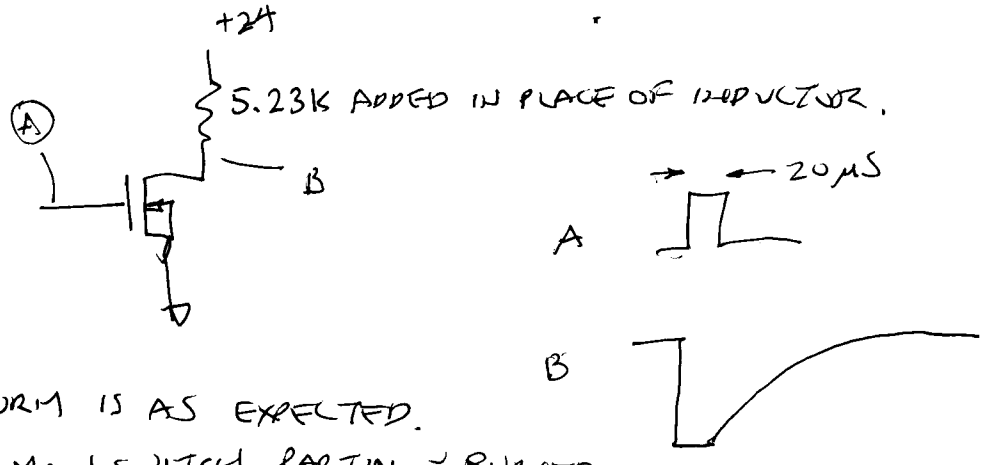
17 FEB15
Roderick.

CONNECTED GATE WINDING & RE-RAN TEST, ONE 20μS PULSE PER SECOND. AFTER 48 ~~PULSE~~ PULSES, OUTPUT HAD RISEN TO COUNT OF 298. BUT THEN, TICKING SOUND THAT NORMALLY ACCOMPANIED TEST GOT SILENT. OUTPUT VOLTAGE BEGAN TO DECLINE. ~~VOLTAGE~~ MAYBE VOLTAGE SPIKE DESTROYED SYNC RECTIFIER? DISCHARGED OUTPUT CAP TO 243 AND RESTARTED - STILL NO CLICKING SOUND, NO RISE IN VOLTAGE. IF TRANSISTOR DESTROYED, CAN'T DO ANY FURTHER DAMAGE. DISCHARGING OUTPUT CAP COMPLETELY. STILL NO CLICKING OR VOLTAGE RISE.

IS MAIN SWITCH BURNED OUT?
REMOVED SYNCHRONOUS RECTIFIER. ~~GATE~~ DRAIN-TO-SOURCE CONDUCTING IN BOTH DIRECTIONS. -NO, AFTER GROUNDING GATE, SHOWS FORWARD VOLTAGE OF ABOUT 673 mV. INFINITE OTHER WAY. PART # FDPF085N10A

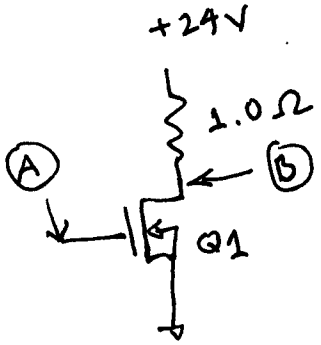
MAYBE MAIN SWITCH BLEW FROM TRANSIENT OVERVOLTAGE, OR OVERCURRENT FIGHTING SYNCHRONOUS RECTIFIER?

18FEB15. LEFT MAIN SWITCH IN CIRCUIT LIKE THIS:

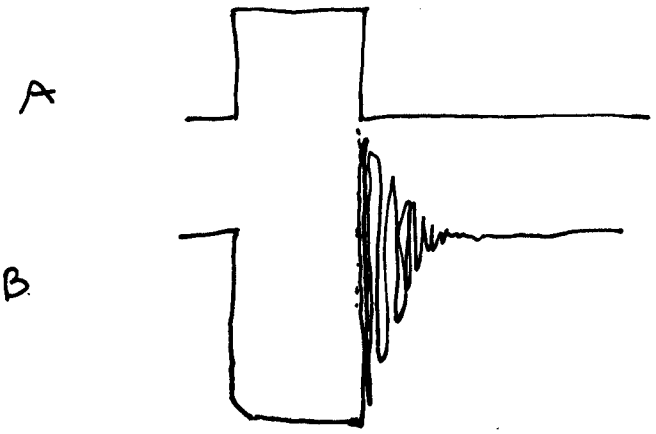


WAVEFORM IS AS EXPECTED.
MAYBE MAIN SWITCH PARTIALLY BURNED OUT?
OR UNRELATED WIRE CAME LOOSE? WHY DID IT HAPPEN JUST AS GATE WINDING CONNECTED?

19FEB15; Roderick.



TRY EXPERIMENT AGAIN WITH 1.0Ω RESISTOR. POINT IS TO SEE WHETHER Q1, THE SUSPECT TRANSISTOR, NO LONGER HAS LOW R_{ON}. WILL USE SAME PROGRAM AS BEFORE, 20μS PULSES, 1 Hz FREQUENCY.



RINGING IS EXPECTED, I CONNECTED RESISTOR OVER LONG JUMPER WIRES. POINT IS, THE TRANSISTOR IS CARRYING THE CURRENT JUST FINE. MAYBE A WIRE JUST CAME LOOSE ON THE PROTOTYPE? SHOULD HAVE PROBED BEHAVIOR BEFORE UNSOLDERING PARTS.

TESTED THE FDPF085N10A. FORWARD VOLTAGE OF BODY DIODE 673 mV. INFINITE RESISTANCE ~~[illegible]~~ W/ GATE GROUNDED. APPLIED 15V TO GATE (GATE TO SOURCE); AND SOURCE TO DRAIN IS 2mV EITHER DIRECTION.

FOUND COLD SOLDER JOINT ON DRAIN OF MAIN SWITCH. REFLOWING.

HOOKED UP W/ PLAIN SCHOTTKY DIODE FOR RECTIFIER. CLICKING SOUND IS GONE. BUT VOLTAGE RISE ON OUTPUT VERY SLOW, COULD IT BE THAT INDUCTANCE IS REALLY ORDER OF 240μH, MAIN INDUCTOR JUST HAD SHORTED WINDING?

IWME3DHG4243213 005139 0007/0007 00

BUT INDUCTANCE METER CHEAP

WHY ~~A~~ TRACE GOES BELOW GROUND?

~~REMO~~ CHEAP SCOPE, HAPPENS EVEN ON BATTERY POWER

~~STOP~~

CHANGED 1.0 Ω TO 0.05 Ω, CHARGING MUCH FASTER.

CHANGED 0.05 → 0, CHARGE FASTER OUTPUT TO 30V NO PROBLEM

CHANGED SYNCHRONOUS RECTIFIER Q2 BY - CONNECTING ADDT'L WINDING OF L1 TO GATE OF Q2 - CHARGED EVEN FASTER, BUT HIT ABOUT 9 VOLTS OUT, AND CLICKING STOPPED. VOLTAGE ROSE NO FURTHER.

OH NO, BURNED IT OUT. PULLED Q2, TESTED OK. CHECKED Q1 IN CIRCUIT, OK. WIRE AT DRAIN OF Q1 COLD SOLDERED - WIRE COULD SPIN WITHIN SOLDER BALL. REFLOWED.

CLICKING SOUND GONE NOW, ~~BUT~~ CHARGING CAP THROUGH ORDINARY SCHOTTKY RECTIFIER, NOT SYNC RECTIFIER. BUT CHARGING ~~SEE~~ IS SLOW.

IWME3DHG5032115 006640 0006/0006 00

21 FEB 2015;
Roderick.

AFTER CLICKING VANISHED, INSERTED 1.0Ω 5 OHM RESISTOR AGAIN. TOOK TRACE WITH 20μS PULSES, AND SAW SLOPE OF CURRENT AS 1.875A/20μS, SUGGESTING THAT INDUCTANCE WAS REALLY 240μH OR SO. RAN 1 PULSE EVERY SECOND, AND SAW OUTPUT VOLTAGE RISING VERY SLOWLY. CHANGED PICAXE PROGRAM FOR 40μS PULSES. AFTER A FEW PULSES, THE CLICKING SOUND CAME BACK AGAIN. REDUCING BACK TO 20μS, CLICKING SOUND STILL THERE, NOT AS LOUD. TRACE SHOWS BACK TO 12A/20μS - LOW INDUCTANCE AGAIN. MAYBE WHEN I WOUND WIRES, SOME TURNS SHORTED TO THE CORE, & THE CORE IS ELECTRICALLY CONDUCTIVE (NOT ~~FIBER~~ FERRITE)? OR MAYBE THE CORE MAGNETIZED ITSELF IN ONE DIRECTION? MIGHT NEED TO REWIND CORE, PUTTING KAPTAN TAPE AROUND IT FIRST.

EXPERIMENT: PUT PROBES ON ADJACENT WINDINGS. THE VOLTAGE SEEMS PROPORTIONAL - NOT SURE THAT I SEE ANY WINDING BEING BYPASSED.

EXPERIMENT: IN DARK ROOM, CAN I SEE ANY ARCING ON THE INDUCTOR? NO

EXPERIMENT: IF THERE'S MAGNETIC HYSTERESIS, TRY REVERSE POLARITY ON THE INDUCTOR. COULD IT BE THAT CLICKING IS JUST A SYMPTOM OF HIGH CURRENT? CLICKING GOT LOUDER WITH LONGER PULSE, NOW WITH REVERSE POLARITY, CURRENT/TIME RISE IS <u>VERY</u> SLOW - NEAR UNDETECTABLE. COULD BE I NEED A DIFFERENT CORE MATERIAL. 300mV/20μS. NEED LOWER COERCIVITY?

22 FEB 2015; Roderick

AMIDONCORP.COM HAS TOROIDS. ALSO TOROIDS.INFO POINTING TO PARTSANDKITS.COM.

POWDERED IRON MAY BE THE CORE I ACTUALLY WANT,

T300-26 - 12 TURNS = 12 μH APPROX.

TYPE 2 PERMEABILITY TOO LOW

T300A-26 - 12 TURNS = 24 μH

↳ 1" HIGH

WWW.66pacific.com - TOROID INDUCTANCE CALCULATOR

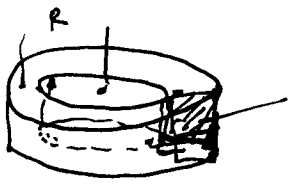
POSTED QUESTION ON ALLABOUTCIRCUITS.COM - DID MY CORE MAGNETIZE? USER alfaclff REPLIED THAT CORE WAS GOING INTO SATURATION.

FROM HYPERPHYSICS SITE, INDUCTANCE OF A TOROID

$$L = \frac{\mu N^2 A}{2\pi R}$$

N = NO. OF TURNS μ = PERMEABILITY OF TOROID MAT'L

A = CROSS SECTIONAL AREA R = AVERAGE RADIUS



REAL DATA R = 5 cm = .05 m

A = 12 mm × 20 mm = 2.4×10^{-4} m²

L = 234 μH

$$234 \times 10^{-6} = \frac{\mu \cdot 12^2 \cdot 2.4 \times 10^{-4}}{2 \cdot \pi \cdot .05} = \frac{\mu \cdot .03456}{0.314}$$

$$\mu = \frac{234 \times 10^{-6} \cdot 0.314}{0.03456} = 2.13 \times 10^{-3} \text{ H/m APPROX}$$

THIS VALUE MATCHES ANNEALED FERRITIC STEEL

23FEB2015; Roderick.

IF μ OF CORE IS $2.13^{\times 10^{-3}}$ H/m, COMPUTE MAGNETIC FIELD AT 24 AMP CURRENT.

$$B = \frac{\mu N I}{2\pi R} = \frac{2.13 \times 10^{-3} \cdot 12 \cdot 24}{2 \times \pi \times .05} = \frac{613 \times 10^{-3}}{.314} = \frac{.613}{.314} = 1.95\ T$$

COULD HAVE BEEN ENOUGH TO MAGNETIZE CORE.

POWDERED IRON AMIDON TYPE 26 PERMEABILITY = 75 (RELATIVE)

T-300A-26 CORE
A_L = 1600 μH / 100 TURNS, MEANING 100 TURNS ON TOROID WILL HAVE INDUCTANCE OF 1600 μH.

IF I USE T-300A-26, INDUCTANCE WITH 12 TURNS WILL BE

$$1600\ \mu H \cdot \left(\frac{12}{100}\right)^2 = \frac{16 \cdot 100 \cdot 12 \cdot 12}{100 \cdot 100} = \frac{2304}{100} = 23\ \mu H$$

$\mu_r = 75$ $\mu_0 = 1.25 \times 10^{-6}$ $\mu = 9.43 \times 10^{-5}$

AVERAGE DIAMETER: 2.49" 63.16mm

$R = 31.6\ mm = 0.0316\ m$ $A = 3.58\ cm^2 = 3.58 \times 10^{-4}\ m^2$

CHECK INDUCTANCE

$$L = \frac{\mu N^2 A}{2\pi R} = \frac{9.43 \times 10^{-5} \cdot 12^2 \cdot 3.58 \times 10^{-4}}{2 \cdot 3.14 \cdot 0.0316} = \frac{4861 \times 10^{-9}}{0.198}$$

$$= 24495 \times 10^{-9} = 24.49 \times 10^{-6} = 25\ \mu H \text{ CLOSE}$$

$$B\ FIELD = \frac{\mu N I}{2\pi R} = \frac{9.43 \times 10^{-5} \cdot 12 \cdot 40}{2 \cdot 3.14 \cdot 0.0316} = \frac{4526 \times 10^{-5}}{0.198}$$

$$= 22860 \times 10^{-5} = 0.23\ T$$

25 FEB 2015; Roderick

IF I GO WITH T-300A-26, WHAT ABOUT CHANCES OF MAGNETIZING CORE AGAIN?

MAGNETIZING FORCE $H = \frac{0.4\pi NI}{\ell_e}$

N = # OF TURNS
I = CURRENT
ℓ_e = EFFECTIVE MAGNETIC PATH LENGTH, CM.

H = FORCE IN OERSTEDS ACCORDING TO AMIDON MATERIAL 26 SPEC SHEET

T-300A CORE O.D. = 3.048", I.D. = 1.925". & ℓ_e LISTED AS 19.83 cm

$$H = \frac{0.4 \cdot 3.14 \cdot 12 \cdot 40}{19.83} = \frac{602.88}{19.83} = 30.4$$

LOOKS LIKE GET ABOUT ~~60~~ 65% OF INITIAL PERMEABILITY AT 30 Oersteds. ALSO, ~~MATERIAL IS~~ SPEC SHEET SAYS "CORES FOR DC CHOKES AND AC LINE FILTERS" SUGGESTING THAT THE MATERIAL MAY BE RESISTANT TO PERMANENT MAGNETIZATION. ELSE, WHY USE IN A DC CHOKE? BUT EVEN IF IT STAYED AT 65% OF μ_i, THAT WOULD BE .65 x 23 μH = ABOUT 15 μH. THAT'S STILL REASONABLE, EVEN IF PERMANENT.

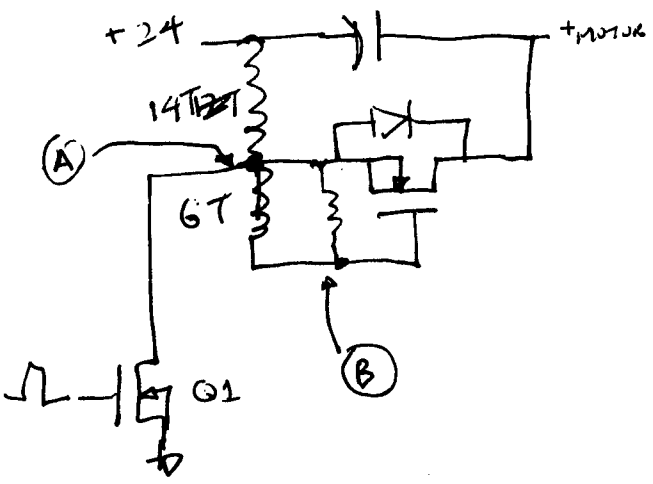
01 MAR 2015

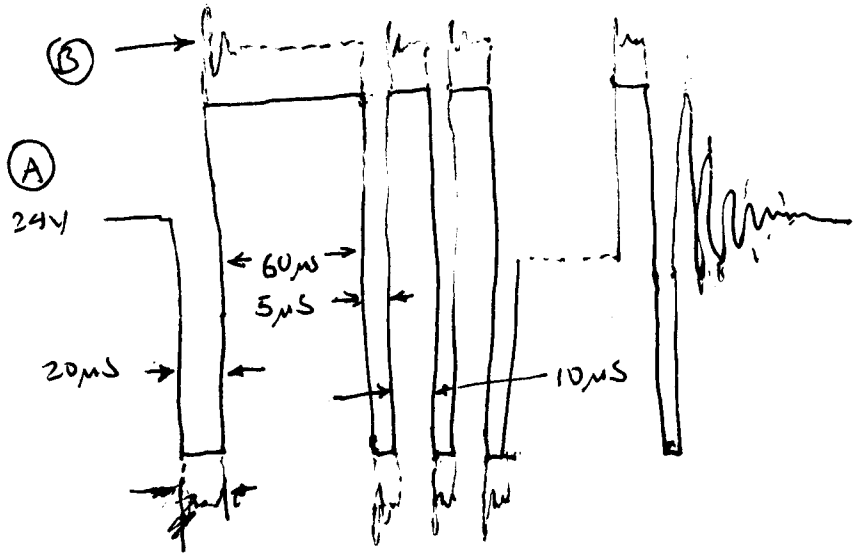
GOT ORDER FROM AMIDON - 2 x T-300-26, 1 x T-300A-26, 1 x T-300-52

WRAPPED 12 TURNS AROUND T-300A-26, #24 OR 26 SOLID WIRE. METER READS 25.6 μH - RIGHT ON THE NOSE.

04 MAR 2015;
Roderick.

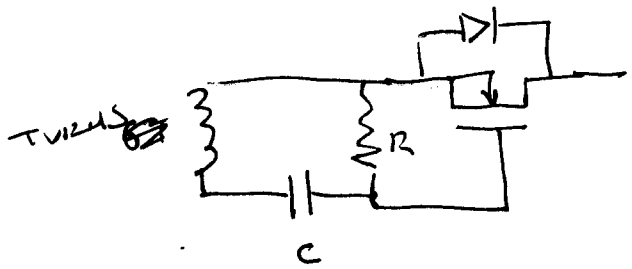
LATEST SYNC RECTIFICATION EXPT





(A) AND (B) BOTH HAVE RINGING, CAN SNUB THAT OUT LATER.

FIRST 60μS PULSE INTO CAPACITOR IS EXPECTED - SAME AS ~~BOTH~~ IN CASE WITH JUST PLAIN RECTIFIER. MY THEORY IS THAT SYNCHRONOUS RECTIFIER IS NOT TURNING OFF IN TIME, SO IT ENDS UP CONDUCTING FROM +MOTOR TO A VOLTAGE ACROSS INDUCTOR SO NEGATIVE, IT MAKES BODY DIODE OF Q1 CONDUCT BELOW GROUND. WILL TRY TO LIMIT PULSE WIDTH ON GATE OF SYNC RECTIFIER.



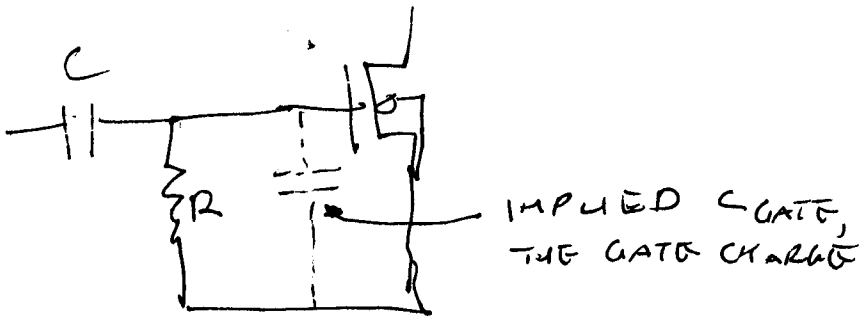
CHOOSE ~~RC~~ SO THAT TURNS
CAN NEVER PUT MORE ~~THAN~~ VOLTAGE
~~10V ACROSS C, SO IT~~
THAN WOULD BE BOOSTED
TO 20V

MAIN TOROID = 12 TURNS, COULD GO ~~TO~~ TO ~~70~~ VOLTS -
-40 TO +30

~~N~~ $\frac{\text{TURNS}}{12} = \frac{20}{70}$ TURNS < 3

3

04 MAR 2015;
Roderick.

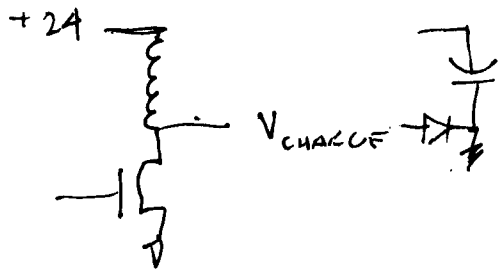


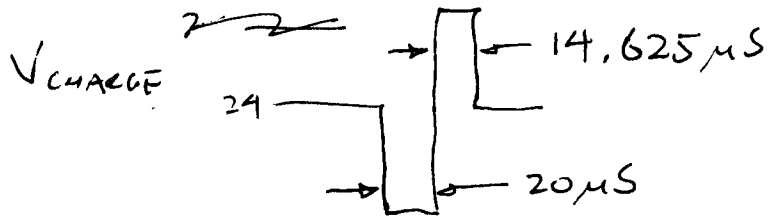
VGATE = -10 MAX AT END OF CHARGE

= +17.5 ~~AT~~ ON FLYBACK

GATE CHARGE = ~~30~~ 30-40 nC @ 10V

$Q = CV \quad C = \frac{V}{Q} = \frac{30 \times 10^{-9}}{10} = 3\,nF = 3000\,pF$





MEASURED DISCHARGE PULSE WIDTH WHEN NEAR MAX OUTPUT VOLTAGE. WIDTH IS 14.625 µS APPROX, SO GATE OF SYNC RECTIFIER MUST TURN OFF BEFORE 14.625 µS, IN LOOKING AT TRACE, ONLY SEEING CONDUCTION WHEN V_{gate} = 3.9 VOLTS. GOT THAT FROM TURNS RATIO ON TOROID, AND NOTING VOLTAGE ON MAIN WINDING WHEN IT LEVELED OUT WITH SYNC RECTIFIER.

SO WANT GATE VOLTAGE TO DECAY FROM 17.5 TO 3.5 IN 14 µS. USE .01 µF CAP, LARGER THAN GATE CAPACITANCE.

$$3.5 = 17.5\left(1 - e^{-\frac{14 \times 10^{-6}}{RC}}\right)$$

05MAR2015; Roderick.

$V = V_0 \left(1 - e^{-t/RC}\right)$.

C = .01μF IN PARALLEL W/ GATE (IN ACTUAL SENSE), SO USE 14nF

$$3.5 = 17.5 \left(1 - e^{-14\times10^{-6}/(R \cdot 14\times10^{-9})}\right)$$

$$\frac{3.5}{7.5} = 1 - e^{-10^3/R}$$

$$e^{-10^3/R} = 1 - \frac{3.5}{7.5} = .533$$

$$\frac{-10^3}{R} = -.629$$

$$R = \frac{1000}{.629} = 1590\ \Omega$$

THESE CALCULATIONS ARE JUST FOR THE BREADBOARD, OF COURSE. REAL VALUES WOULD BE RECALCULATED IF THE PROOF OF CONCEPT WORKS.

Q: AREN'T YOU LOSING EFFICIENCY WITH THIS SCHEME, SINCE THE SYNCHRONOUS RECTIFIER ISN'T ON AS LONG AS IT COULD BE, ESPECIALLY FOR LONG PULSE WIDTHS?

A: A LITTLE, BUT IF I DESIGN AROUND THE MAX POWER OPERATING POINT, I'LL GET EFFICIENCY WHERE IT COUNTS. I WOULD USE THE SAME WIDTH PULSES, JUST SPACED WIDER APART, FOR LESS POWER.

TRIED ON ACTUAL BREADBOARD - NEEDED TO USE 1.0K = R, 0.01μF = C TO MAKE IT WORK UP TO 32V. CONCEPT VALIDATED.