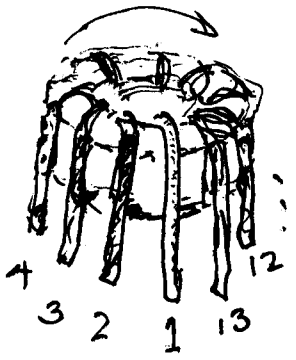
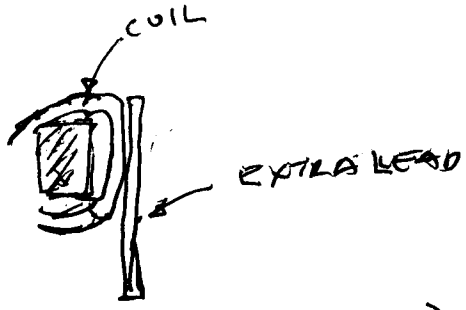
30 JAN 2015; Roderick.

WOUND CUSTOM ~~TOROID~~ TORDID



LEAD 1 IS DIRECT WIRE

LEADS 2-13 HAVE EXTRA WIRE SOLDERED ON TO EDGE OF COIL



INDUCTANCE MEASURED LEADS (INCLUDING JIG)

1-2	4.0 μH
2-3	3.9 μH
3-4	3.9
4-5	3.9
5-6	4.0
6-7	4.0
7-8	4.0
8-9	4.0
9-10	4.0
10-11	4.0
11-12	4.0
12-13	4.0

1-3	8.4 μH
1-4	15.6
1-5	25,8
1-6	38.9
1-7	55.0
1-8	74.3
1-9	96.5
1-10	122.5
1-11	152.7
1-12	188.0 μH
1-13	0.234 mH

02 FEB 2015;
Roderick.

PREVIOUS EQUATIONS

V = INPUT SUPPLY

L = INDUCTANCE OF MAIN TOROID

t = CHARGING TIME, HALF OF PERIOD

P = ~~OUTPUT~~ INPUT POWER (OUTPUT ASSUMED SIMILAR)

~~$V_F = R$~~

$$t = \frac{4PL}{V^2}$$

SAG IN INPUT CAP VOLTAGE (DISREGARDING PANEL)

C = INPUT CAPACITANCE

V_F = FINAL CAPACITOR VOLTAGE AFTER CHARGING INDUCTOR

ALSO MAKE ASSUMPTION THAT SAG IS SMALL, ELSE EQUATION INVALID.

$$V_F = \sqrt{V^2 - 16\frac{P^2 L}{C V^2}}$$

$$C = \frac{16P^2L\,(V^2 - V_F^2)}{V^2(V^2 - V_F^2)} = \frac{4Pt\,(V^2 - V_F^2)}{(V^2 - V_F^2)} = \frac{4Pt}{(V^2 - V_F^2)}$$

SUPPOSE I ACTUALLY WANT TO USE ENTIRE 12 WINDINGS OF TOROID @ 234 μH, ASSUME P = 200W WORST CASE, V = 24 VOLTS

$$t = \frac{4 \cdot 200 \cdot 234 \cdot 10^{-6}}{24^2} = 325 \times 10^{-6} \quad 325\,\mu S$$

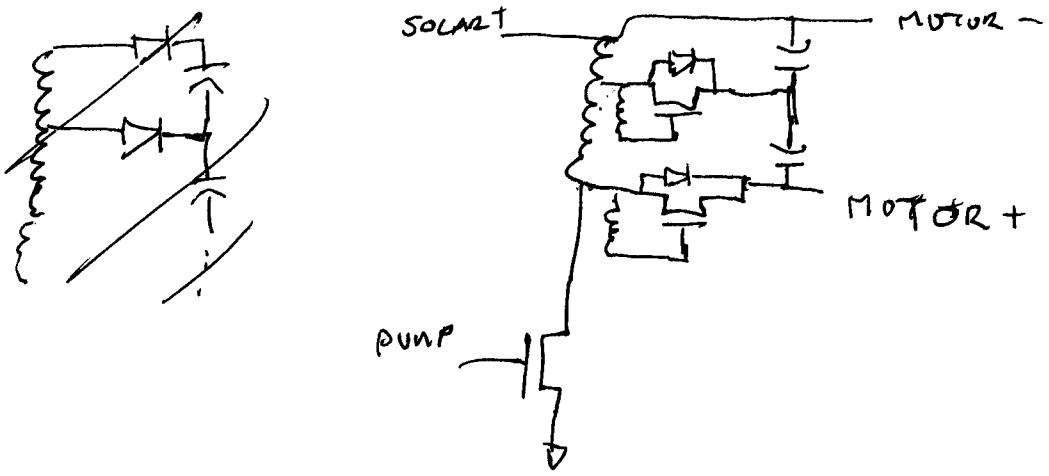
FOR 1 VOLT DROOP

$$C = \frac{16 \cdot 200^2 \cdot 234 \cdot 10^{-6}\,(24^2 - 23^2)}{24^2} = 4 \cdot 200 \cdot 325 \times 10^{-6} / (576 - 529)$$

$$= \frac{260\,000}{47} \times 10^{-6} \approx 553\,\mu F$$

04FEB15; Roderick.

PROBLEM WITH USING SINGLE INDUCTOR TO CHARGE CAPACITOR STACK?



CAN V_{GS} OF SYNC RECTIFIERS EVER GO OUT OF SAFE ZONE?

WHEN PUMPING, V_{DS} MAY BE 40+30 = 70V FOR BOTTOMMOST RECTIFIER. BUT V_{GS} SHOULD BE BASED ONLY ON TURNS RATIO BETWEEN WHOLE INDUCTOR AND GATE WINDING.

WOULD LIKE V_{GS} TO BE LARGE AS POSSIBLE FOR QUICK TRANSITIONS. BUT WAIT, IS THAT TRUE? IT'S TRUE FOR RESISTIVE DRIVE. WITH TRANSFORMER, THE WINDING WILL TAKE ALL THE CURRENT IT CAN OVERCOMING THE MILLER CAPACITANCE OF THE GATE BEFORE IT LETS ANY OF THE MAIN WINDINGS RISE HIGHER. HIGHER V_{GS} DOES MEAN SLIGHTLY LOWER $R_{DS(ON)}$ THOUGH.

BUT CANNOT VIOLATE ±20V V_{GS} RATING OF ALL THE COMMON MOSFETS I'M CONSIDERING.

IF MAIN INDUCTOR IS 12 TURNS, AND -40V MAX DURING PUMP, 6 TURNS FOR GATE WINDING WOULD BE -20V.

WILL MAKE TABLE ON NEXT PAGE.

04FEB15; Roderick.

GATE WINDING VOLTAGES - ASSUME DRIVE 12T OF INDUCTOR
PUMP VOLTAGE = 40V CAPACITOR STACK VOLTAGE = 30V

GATE TURNS	PUMP V_{GS}	CHARGE V_{GS}	
6	-20	15	; RIGHT ON THE EDGE
5	-16.7	12.5	← USE THIS, HAS MARGIN
4	-13.3	10	
3	-10	7.5	
2	-6.7	5	; TOO LOW

IF DECIDE TO DRIVE 8T OF MAIN INDUCTOR ONLY

GATE TURNS		
6	-30	22.5
5	-25	18.75
4	-20	15
3	-15	11.25
2	-10	7.5

GIVE UP ON DRIVING INDUCTOR AT MIDDLE TAP. ONLY ADVANTAGE WOULD BE HIGHER OPERATING FREQ. DRIVING WHOLE INDUCTOR WILL DISTRIBUTE MAGNETIC FIELD AROUND TOROID BETTER.

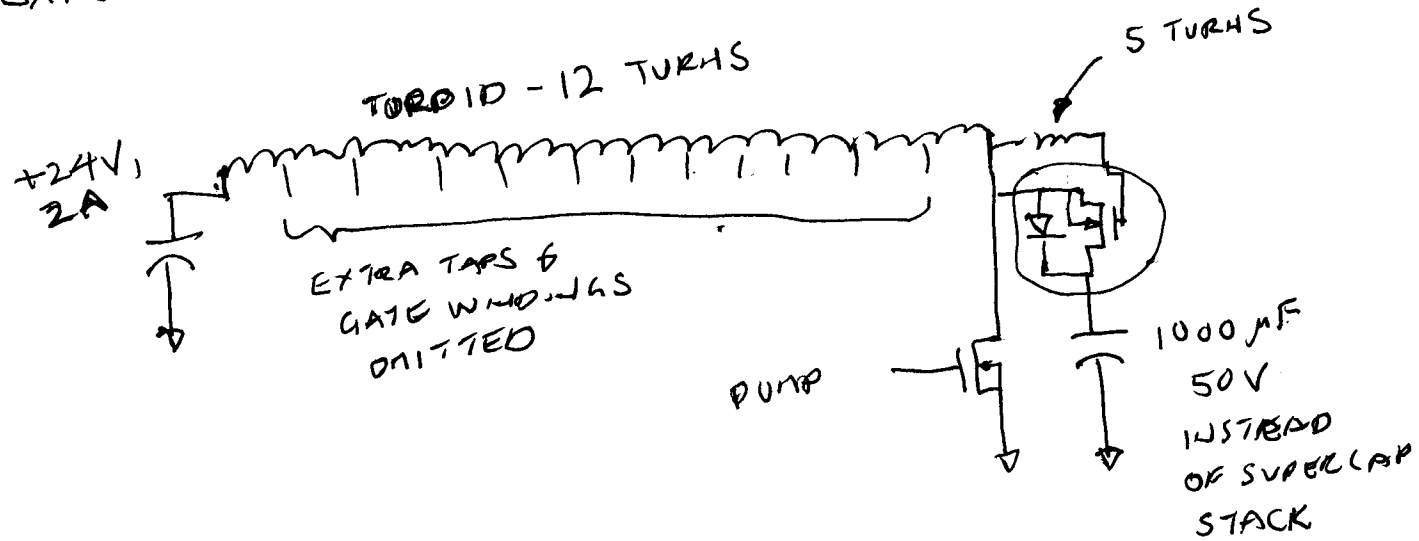
BUT WHAT IF ACTUAL SOLAR INPUT IS 24 VOLTS?
CHARGE $V_{GS} = 24 \cdot 5/12 = 10$ V THAT'S OKAY

05FEB15 ; Roderick.

IF I USE 5 TURNS ON GATE WINDING, GATE VOLTAGE = 5/12 OF THE VOLTAGE ACROSS THE WHOLE INDUCTOR. IF THE SOLAR INPUT IS 12 VOLTS, THE SYNCHRONOUS RECTIFIERS WOULD BE DRIVEN BY JUST 5 VOLTS = V_{GS}. BARELY BETTER THAN JUST PLAIN ~~RECTIF~~ PASSIVE RECTIFIERS. COULD RUN WITH 12 VOLT INPUT JUST TO SHOW IT WORKS, BUT WOULDN'T BE AS EFFICIENT. BIG SOLAR PANELS AREN'T 12 VOLTS ANY MORE, ANYWAY. DROP 12 VOLT INPUT AS A REQUIREMENT. COULD REWORK BOARD & DRIVE INDUCTOR AT MIDDLE TAP FOR 12 VOLTS. NOT TRUE - V_{GS} = 5/12 OF OUTPUT VOLTAGE, STILL GOOD.

SOFTWARE SHOULD DETECT INPUT VOLTAGE OUT-OF-RANGE AT INIT, AND FLASH ERROR LIGHT. RS-232 CONNECTION REQUIRED FOR DETAIL.

EXPERIMENT:



06FEB2015;
Roderick

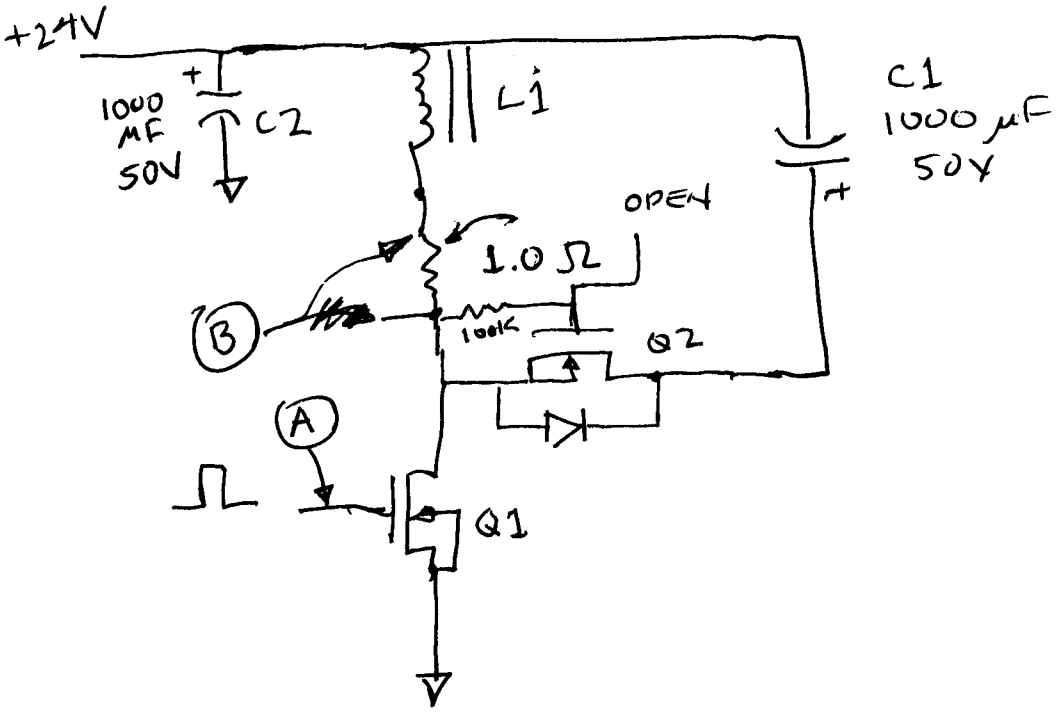
WILL RUN EXPERIMENT ON PREVIOUS PAGE. HAVE A POWER BRICK CAPABLE OF 24V, 2A. HAD SLA BATTERIES BEFORE, BUT THEY WENT BAD. SO WILL ONLY ~~CHARGE~~ PUMP INDUCTOR TO 2A FOR THIS TEST.

$$dI = \frac{V}{L}\,dt \qquad 2 = \frac{24}{234\times10^{-6}}\,dt$$

$$2 = \frac{24}{24\times10^{-5}}\,dt \qquad dt = 20\times10^{-6} = 20\,\mu S.$$

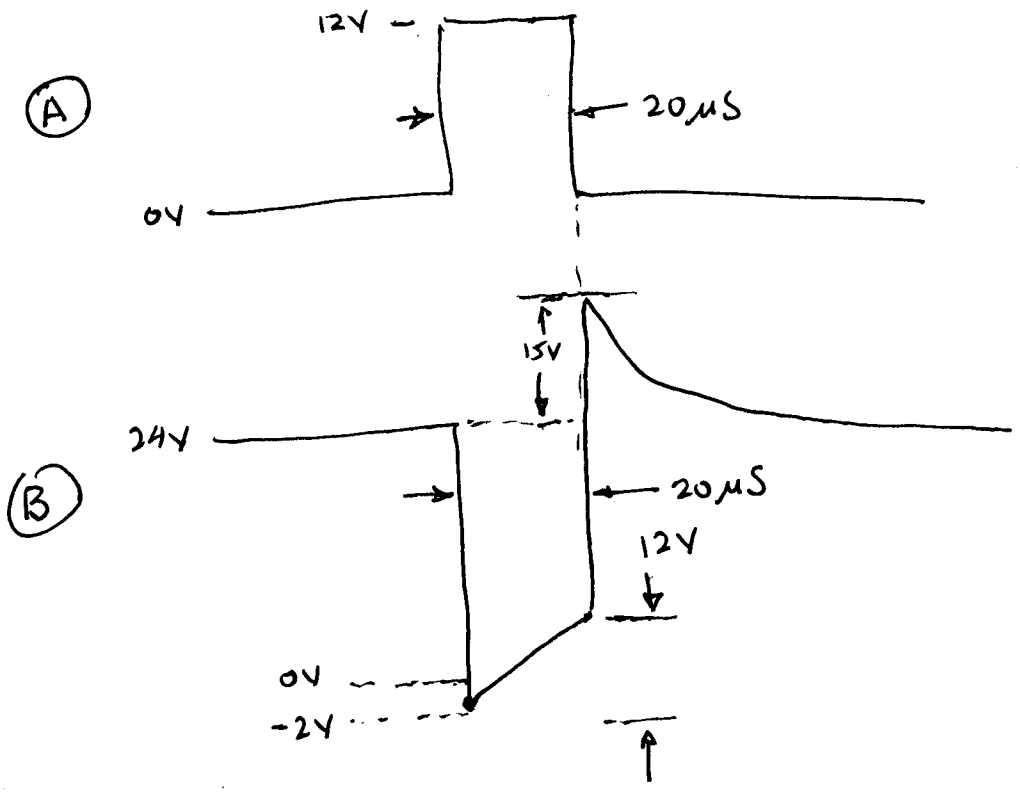
MUST CHANGE PICAXE PROGRAM TO DELIVER SINGLE PULSE OF THIS ~~MAGNI~~ DURATION.

10 FEB 2015; Roderick



HOOKED UP EXPERIMENT, PUT 20mS, 12 V PULSE IN AT (A). VOLTAGE ON C1 ONLY RISES BY 0.01 TO 0.02V PER PULSE. SHOULD BE MUCH MORE, LIKE 1 VOLT IF 100% EFFICIENT. I WAS THINKING THAT INDUCTOR MIGHT BE LARGER THAN MEASURED, OR SOMETHING IN THE DRIVE PATH IS OTHERWISE NOT ALLOWING THE FULL 2 AMPS TO BUILD UP. CAN'T BE DC RESISTANCE OF L1 - THAT JUST ABOUT 1 METER OF #12 COPPER. MAYBE C2 WAS NOT SUPPLYING ENOUGH CURRENT, OR 24V SUPPLY JUST TOO WEAK? COULDN'T BE Q1 NOT TURNING ON, COULD IT? NEEDED TO PROBE CIRCUIT - PUT SCOPE AT POINTS (A) AND (B)

10 FEB 2015 ; Roderick



3 THINGS STRANGE:

1) LOOK AT SLOPE OF VOLTAGE ACROSS 1Ω RESISTOR. 12V RISE IN 20µS. IF DRIVEN BY AN AVERAGE VOLTAGE OF 18V, THAT SUGGESTS L1 IS REALLY 30µH, NOT 240µH.

2) UNDERSHOOT BELOW GROUND. ON A PREVIOUS TRACE WITHOUT THE 1Ω RESISTOR, THE BOTTOM OF THE (B) TRACE WAS FLAT, AT -5V OR SO, FOR THE WHOLE 20µS. NOT JUST AN UNDERSHOOT.

3) WHEN Q1 TURNS OFF, I EXPECT (B) TO JUMP, BUT THEN EITHER STAY FLAT OR SLOWLY RISE, AS THE CAPACITOR C1 CHARGES. EXPONENTIAL DECAY IS NOT EXPECTED.

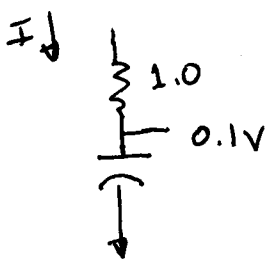
12 FEB 15 ; Rodrick.

REGARDING QUESTIONS FROM 10FEB15 (ANOMALIES):

1) SUBSTITUTED ~~0.1~~ 0.05 Ω INSTEAD OF 1.0 Ω AS SENSE RESISTOR. STILL SEE RAPID JUMP IN CURRENT, SUGGESTING 24 A AFTER 20 μs, (1.2 V ACROSS 0.05 Ω). THAT WOULD MAKE INDUCTOR $\frac{24V}{24A} \cdot 20\mu s = 20\mu H$.

OKAY, SO MAYBE THE DM4070 METER IS NOT A GOOD MEASURE FOR INDUCTANCE AT HIGH CURRENTS? IF L1 IS REALLY 20 OR 50 μH, ALL THE BETTER FOR DESIGN - WON'T HAVE TO GO TO LOWER FREQUENCIES, AND CAN USE SMALLER INPUT CAPACITORS.

ALSO NOTED THAT WITH 0.05 Ω, OUTPUT VOLTAGE JUMPS 0.25, MAYBE 0.35 V AT A TIME. MAKES SENSE.



FOR SHORT PULSE OF 12 AMPS, 12 V DEVELOPS ACROSS R. P = IR, SO ONLY 4% OF POWER GOES INTO CAP (DISREGARDING THAT VOLTAGE RISES).

IF R = 0.05 Ω, VOLTAGE IS 12/20 = 0.6 V

~~MEANS~~ MEANS ~ 15% OF POWER GOES TO CAP

DISREGARDS DIODE DROP OF ~~NON-SYNCHRONOUS~~ PASSIVE RECTIFIER, WHICH IS SIGNIFICANT.

THIS TELLS ME THAT OUTPUT RESISTANCE MATTERS A LOT, AND THAT THERE IS AN EFFICIENCY LIMIT AT LOW VOLTAGES, ~~LIKE~~ & HIGH CURRENTS, ~~EVEN~~ A CONCERN WHEN INDIVIDUAL SUPERCAPS ARE CHARGED TO JUST 2.5 V. MAKES SYNCHRONUS RECTIFICATION A MUST.

12FEB15; Roderick.

MORE EXPERIMENTS:

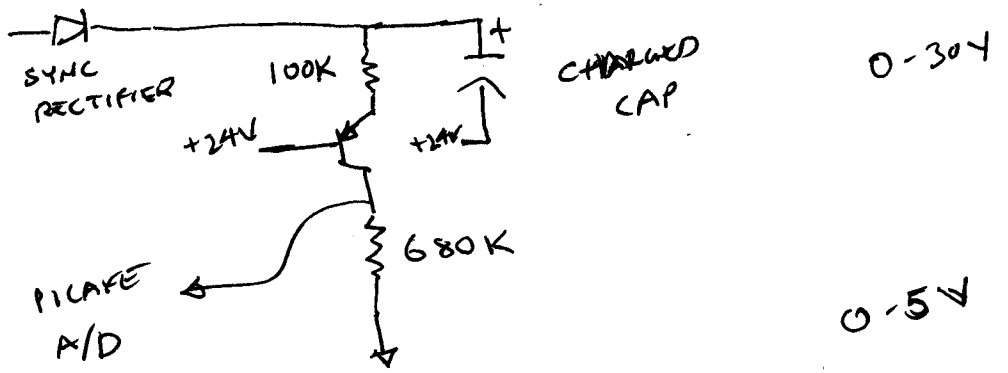
CHARACTERIZE VOLTAGE VS INDIVIDUAL PULSES FOR 0.05Ω RESISTOR SETUP, THAN AGAIN WITH RESISTOR REMOVED (SHORTED).

PULSE	VOLTAGE	
0	0.03	; STARTING VOLTAGE
1	0.05	
2	0.07	

UP TO 24V OR 30V IF POSSIBLE.

MAYBE SHOULD USE A/D OF PICAXE, AND PUT OUT ONE PULSE PER SECOND, THEN REPORT OVER RS-232

STOP AFTER REACHING FINAL VOLTAGE

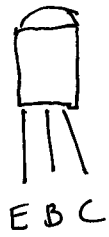


ALSO TRY WITH SYNCHRONOUS RECTIFIER ENABLED.

ALSO TRY CHARGING JUST ONE SUPERCAP - MAY NEED TO JUST USE ONE PULSE PER SECOND (OR 100), AND NOTE RESULTS MANUALLY ON VOLTMETER. BASE-EMITTER DROP ON SENSE CIRCUIT COULD DISTURB ACCURACY AT LOW VOLTAGES.

12FEB15; Roderick.

DECIDED TO DO AUTOMATIC MEASUREMENT.



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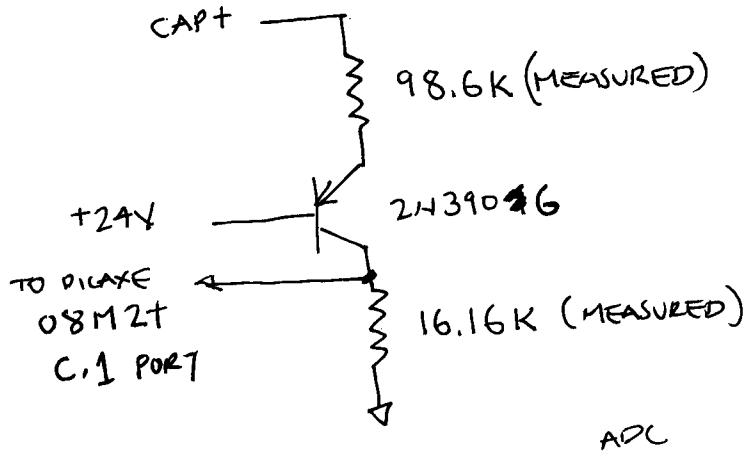
E B C



FULL SCALE VOLTAGE ON PICAXE = 5.0V = ~~1024~~ 1023 ADC UNITS

PICAXE VOLTAGE (V_p) = $\frac{16.16}{98.6}$ · CAP VOLTAGE (V_c)

COUNT

$Cp = \frac{Vp \cdot 1023}{5}$

$V_p = \frac{Cp \cdot 5}{1023}$

$V_c = V_p \frac{98.6}{16.16} \cdot \frac{5}{1023}$

$V_c = Cp \cdot \frac{98.6}{16.16} \cdot \frac{5}{1023}$

V_c ↑ CAP VOLTAGE

Cp ↑ PICAXE COUNT

$\frac{98.6}{16.16} \cdot \frac{5}{1023}$ CONSTANT FOR SPREADSHEET.

WROTE PROGRAM TO PUT OUT ONE PULSE PER SECOND. AT THAT RATE, THE ~~VOL~~ CHARGING LEVELS OUT AT ABOUT 10.6 VOLTS, 100K IS TOO MUCH OF A LOAD, COULD UP THE FREQUENCY OF CHARGING, BUT THINK I SHOULD DETERMINE WHETHER CAN USE 1 MΩ IN TOP RESISTOR AND 162K IN BOTTOM W/ PICAXE. WITH VOLTMETER CONNECTED, CAP CHARGES MUCH HIGHER. DON'T KNOW IMPEDANCE OF METER, BUT IF 50KΩ/VOLT ON 20V SETTING, THAT'S 1 MΩ

13FEB15; Roderick.

CHANGED RESISTORS TO 1M (1005K MEASURED) AND 150K (154.2K MEASURED). NOW CAN ACHIEVE A COUNT OF 951~954, WHICH TRANSLATES TO 30.4V. BUT STILL, IT'S LEVELING OFF WITHOUT REAMING COUNT OF 1000 ON A/D. SO SUGGESTING THAT THE TEST SIG IS STILL DISTURBING THE READING SIGNIFICANTLY. NOTE: GOOD THING I DIDN'T TRY TO MEASURE MANUALLY WITH A VOLTMETER. I REALIZE NOW THAT I WOULD HAVE HAD TO WRITE DOWN HUNDREDS OF FIGURES. ONE MORE THING TO TRY - PUT A CAPACITOR ACROSS LOWER RESISTOR. IF THAT INCREASES THE READING, CONCLUSION WOULD BE THAT A/D ~~IMPEDANCE IS~~ IS DRAWING TOO MUCH CURRENT DURING SAMPLING. IN FACT, MIGHT AS WELL ALWAYS HAVE A SMALL CAP IN FINAL DESIGN. ALSO WANT A PNP TRANSISTOR IN FINAL DESIGN W/ HIGH GAIN @ LOW CURRENT.

CAPACITOR DETERMINATION: GO FOR TIME CONSTANT CONSIDERABLY SHORTER THAN PULSE REPETITION RATE.

SAY, $1\,mS = 10^{-3}$ SEC = 5 TIME CONSTANTS

$\tau = 200 \times 10^{-6} = RC$ R IS 150K PARALLEL 1 MEG.

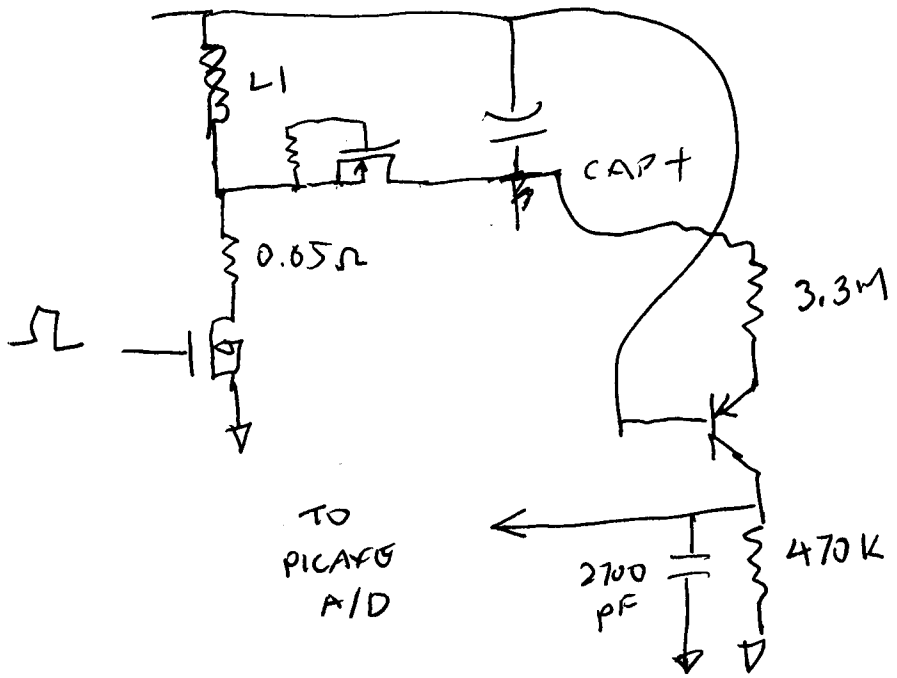
$$C = \frac{200}{150} \times 10^{-9} = 1300\,pF$$

PUT IN 2700pF - ONLY PULSING AT 1 SEC INTERVALS NOW, NOW LEVELING OUT AT 956-959 COUNT, MINIMAL DIFFERENCE.

13 FEB15 ; Roderick.

CHANGED RESISTORS AGAIN. TOP = 3.3M, BOTTOM = 470K.
NOW COUNT IS GOING ALL THE WAY TO 1007, WHERE THE PROGRAM AUTOMATICALLY STOPS PULSING. 862 ~~SEE~~ PULSES TO GET THERE.

REMOVED 0.05Ω RESISTOR, SOLDERING DIRECTLY INSTEAD.
TOOK ONLY 676 ~~COUNTS~~ PULSES TO GET TO 1007



LOOKS LIKE ALMOST ~~25%~~ 27.5% OF POWER LOST TO 50mΩ RESISTOR

$$\frac{862 - 676}{676} = \frac{186}{676} = .275$$

CRITICAL TO KEEP RESISTANCES LOW IN ACTUAL DESIGN.
THIS EXPERIMENT ALSO VALIDATES THE VOLTAGE SENSING ARRANGEMENT.