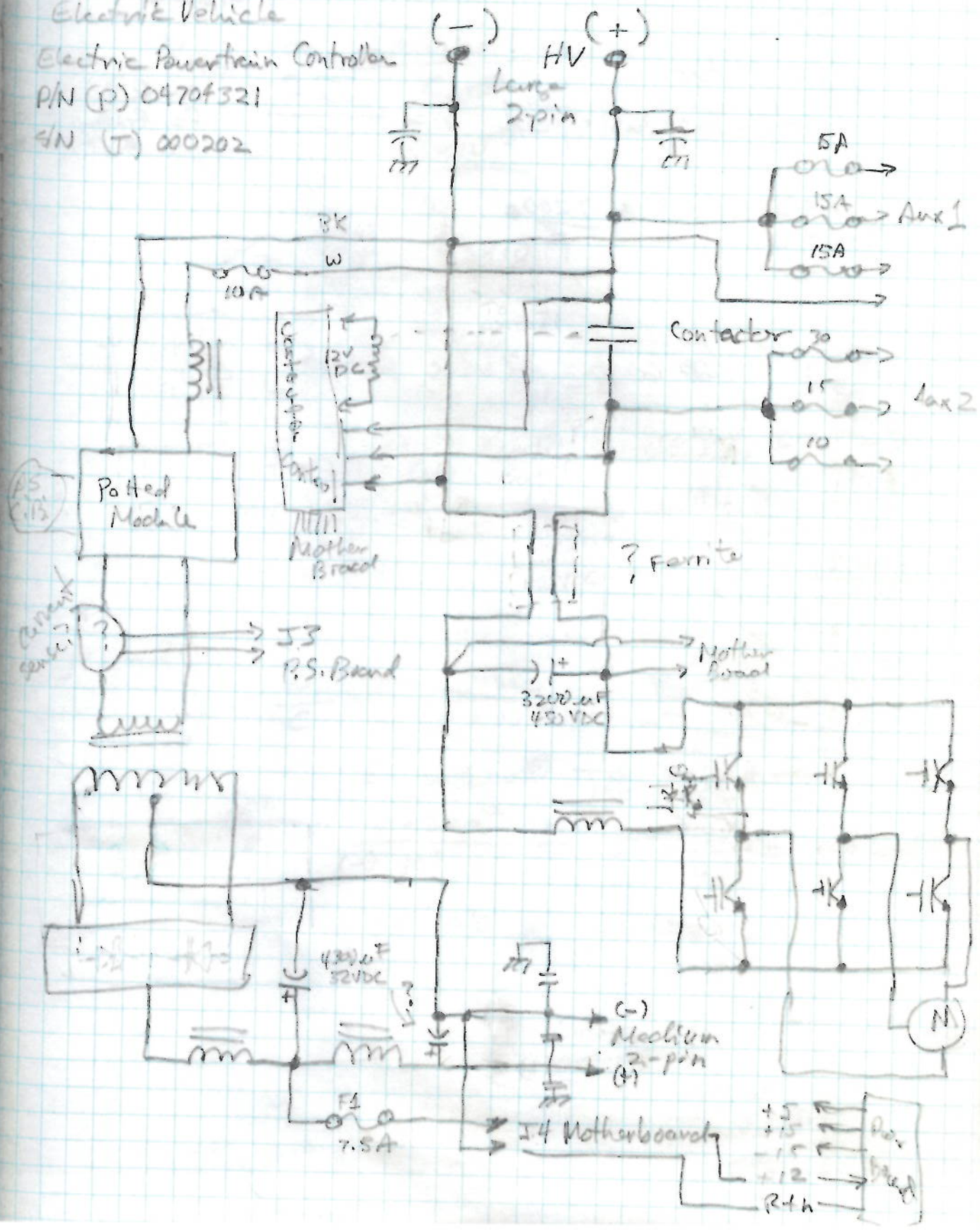
Northrop Grumman
Electric Vehicle

Electric Powertrain Controller
P/N (P) 0470f321
S/N (T) 000202



9 msec

AC Motor

synchronous speed $n = \frac{120 \times f}{p}$

n = RPM
f = freqy, Hz
p = # of poles

$120 \times 60 = \frac{7200}{p}$

p	n
2	3600
4	1800
6	1200
8	900

60 Hz = 17 msec period

$np = 120 \times f$

$f = \frac{np}{120}$

$V_{ripple} = \frac{I \cdot 8.3\,ms}{C}$

$C = \frac{I \cdot 8.3 \times 10^{-3}}{V_r}$

$= \frac{15 \cdot 8.3 \times 10^{-3}}{10}$

$= 12.5 \times 10^{-3}$

$= .0125\,F$

$= 12{,}500\,\mu F$

So $V_R = V = 125{,}000\,\mu F$

$\Delta V = \frac{I}{2fC}$

$\Delta V = \frac{I \cdot 8.3}{C}$

$I = mA$

$C = \mu F$

$\frac{15 \cdot 8.3}{10^{\#}}$

$C = \frac{I \cdot 8.3}{\Delta V}$

$\frac{15^{x\#} \cdot 8.3}{10}$

$\frac{15 \times 10^{3} \times 8.3}{10}$

125×10^{2}

12500

$\tau = RC$

$R = \frac{\tau}{C} = \frac{10\,sec}{10{,}000\,\mu F} = \frac{10}{10^{-2}}$

$= \frac{1}{10^{-3}} = 1\,k\Omega$

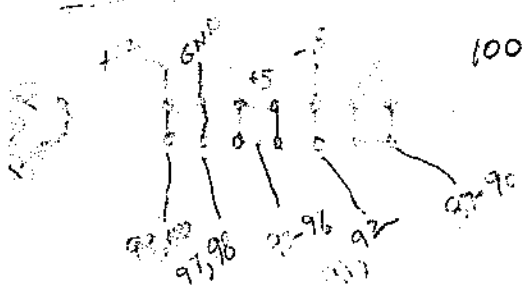
$P = \frac{E^2}{R} = \frac{(1.4 \cdot 220)^2}{103} \cong \frac{100 \times 10^3}{103} = 100\,watts$

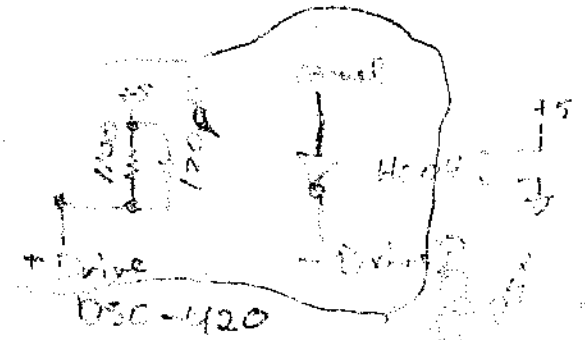
$100\,sec = 10K = 10\,watts$

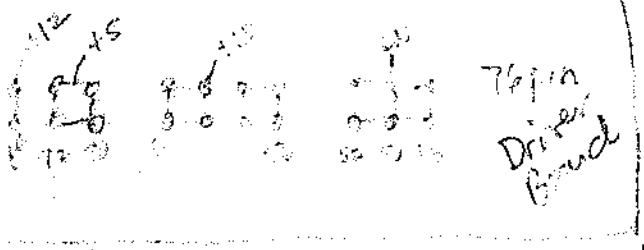
$10{,}000\,\mu F$

$10 \times 10^{3} \times 10^{-6}$

10×10^{-3}







Blue 1 — 2 — 35 — 30 → J1H

Green 7 — 8 — 37 — 32 → J1L

Yellow 9 — 6 — 39 — 34 → J2H

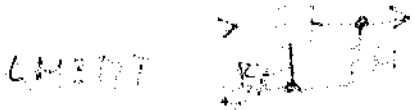
Brown 13 — 12 — 41 — 36 → J2L

Green 3 — 4 — 38 → J3H

Red 11 — 10 — 40 → J3L

H = 6,7

L = 3,4



LM317

$V_O = 1.25 + 1.25 (R2/R1)$

$V_O = 1.25 + \frac{1.25 R2}{R1}$

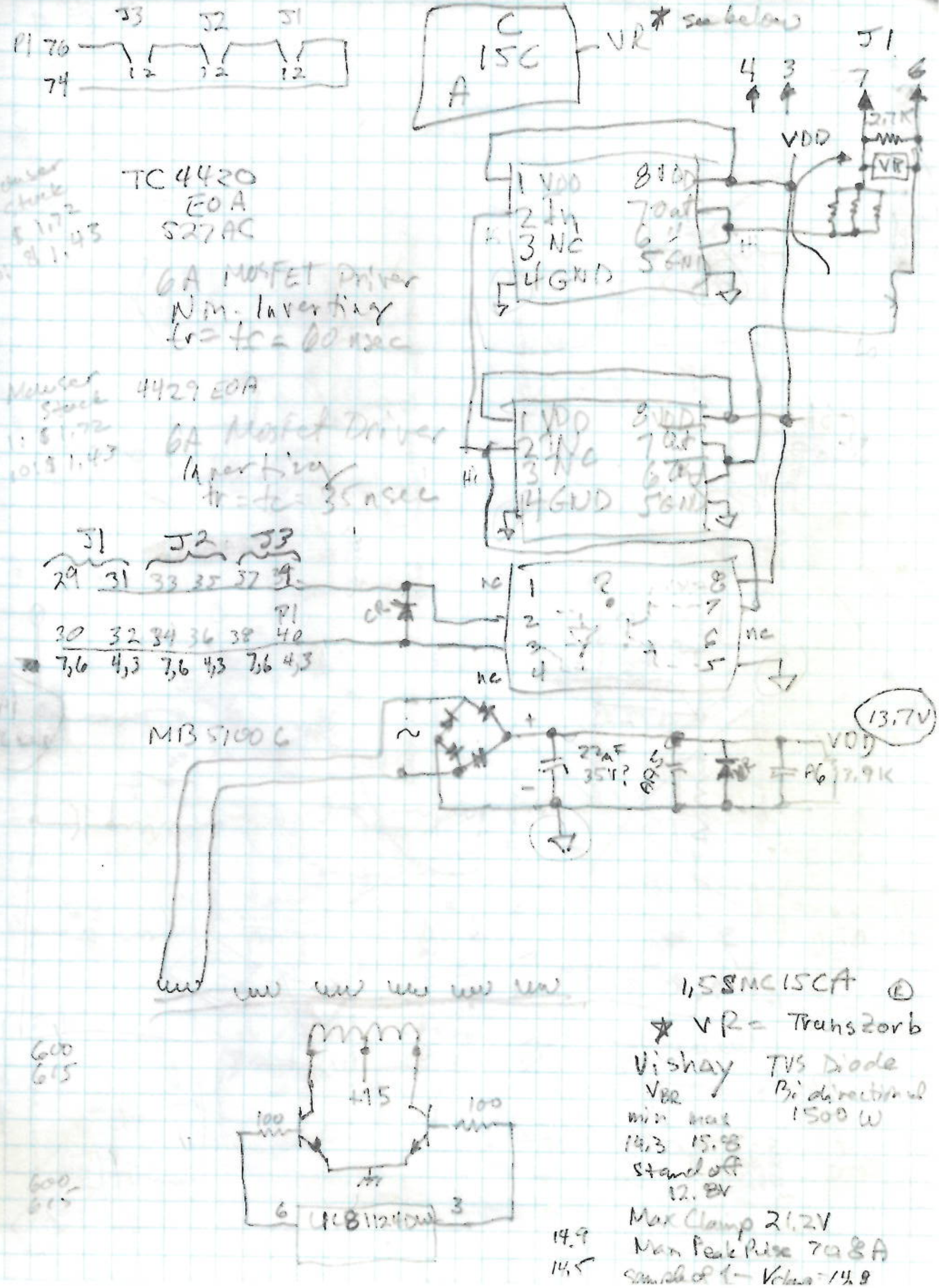
$15 = 1.25 + 1.25 R2/R1$

$13.75 R1 = 13.75$

$R1/R1 = \frac{13.75}{1.25} = 11$

$R1 = 1.0\Omega$ 330 Ω

$R2 = 2.2K$ 2.2K 2K



TC4420
EOA
527AC
6A MOSFET Driver
Non-Inverting
tr = tf = 60 nsec

Mouser stock
1: $1.72
10: $1.43

4429 EOA
6A Mosfet Driver
Inverting
tr = tf = 35 nsec

Mouser stock
1: $1.72
10: $1.43

→ J1 H
→ J1 L
→ J2 H
→ J2 L
8 → J3 H
10 → J3 L

6,7
3,4

MB5100G

1.5SMC15CA (R)

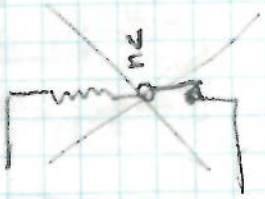
* VR = Transzorb

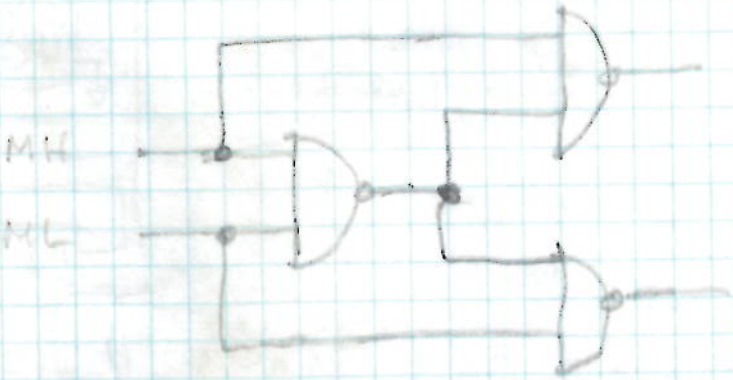
Vishay TVS Diode
Bidirectional 1500 W

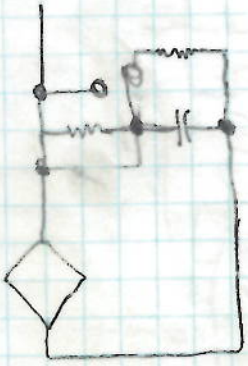
V_{BR}
min max
14.3 15.8

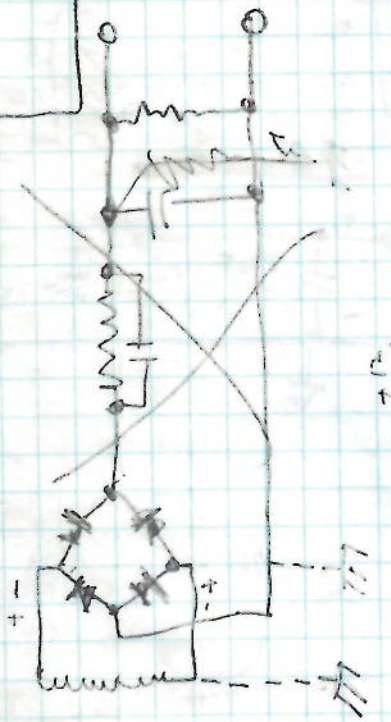
Stand off 12.8V

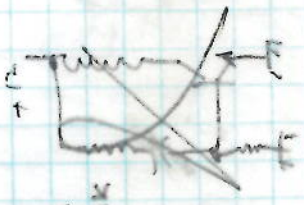
Max Clamp 21.2V
14.9 Max Peak Pulse 70.8A
14.5 sample of 1 — Vclamp 14.8

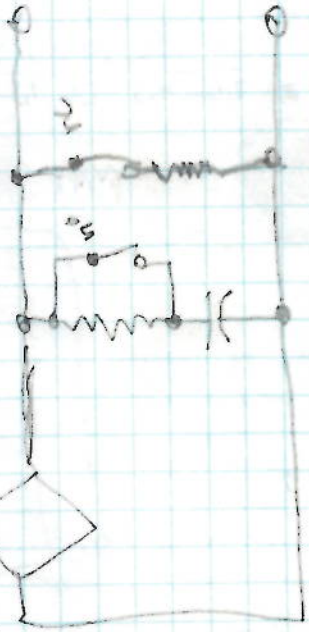


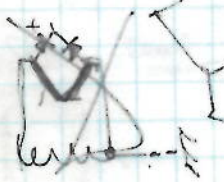

MH
ML

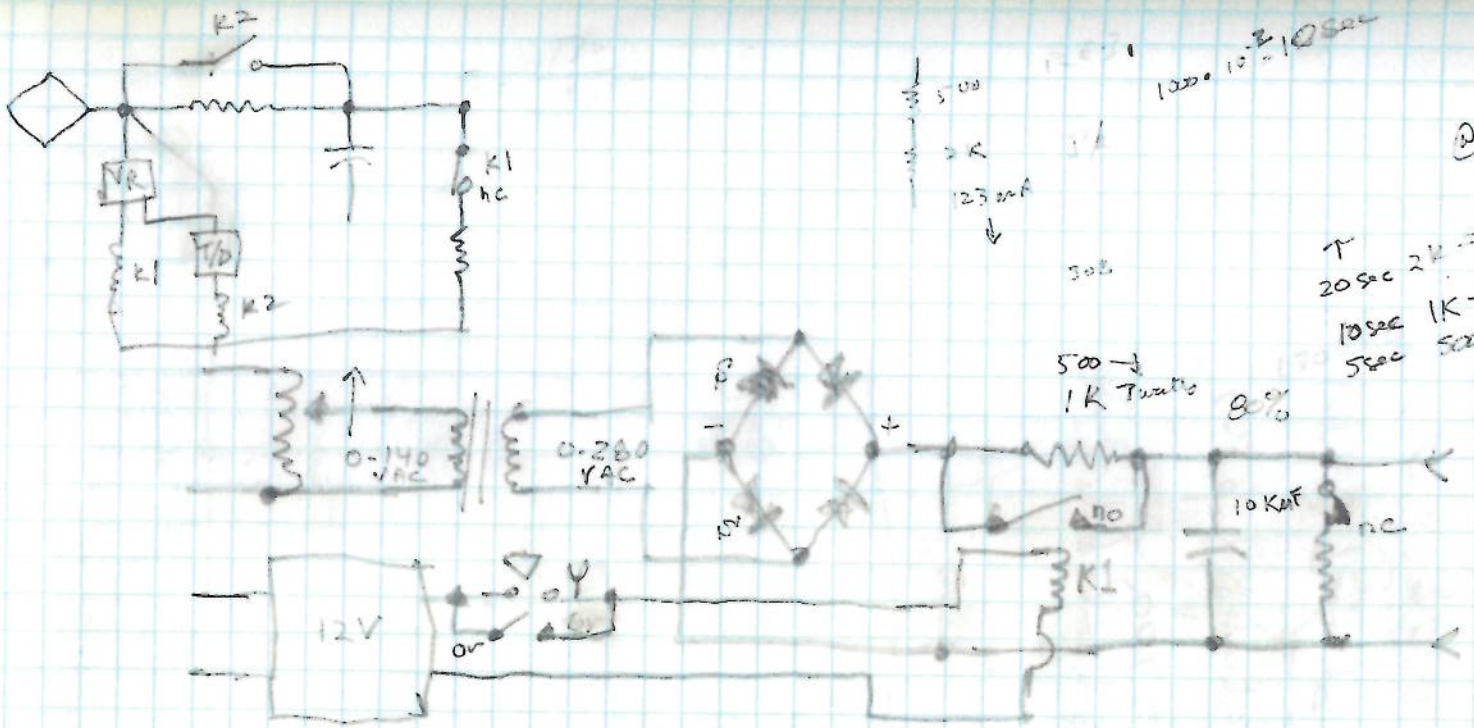


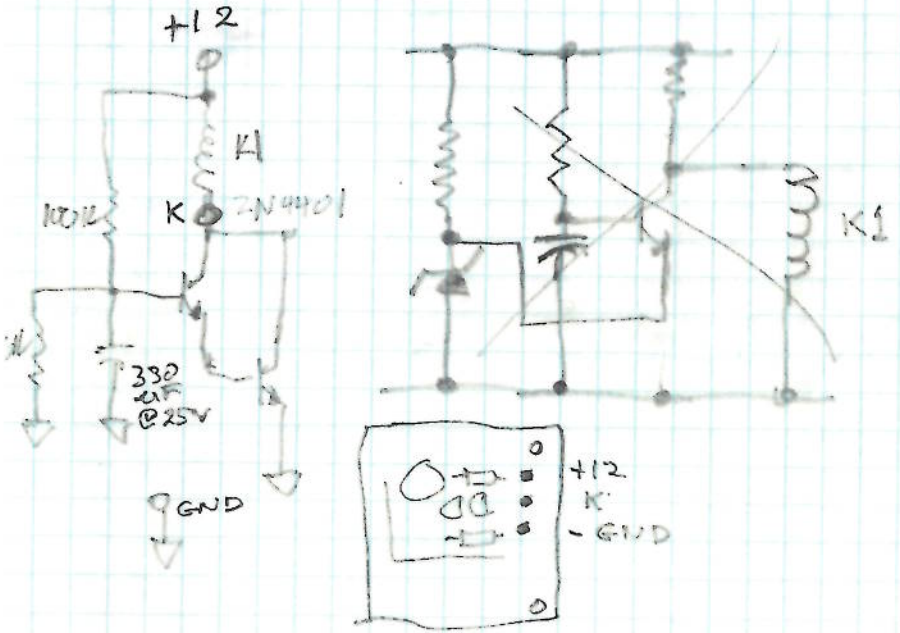


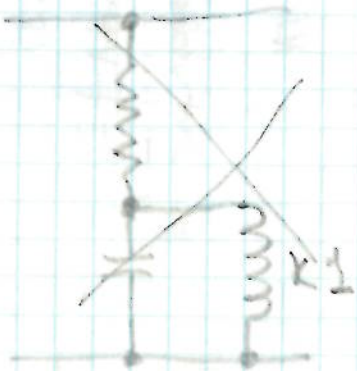












nom. 12 VDC
Operate 9V
86 Ω
140mA @ 12

Driver Board & Bridge Voltage

PS 14.3

From left

1	10.4	
2	10.2	
3	11.1	
4		11.5
5	12.6	
6	10.2	

VR1 2700 Ω

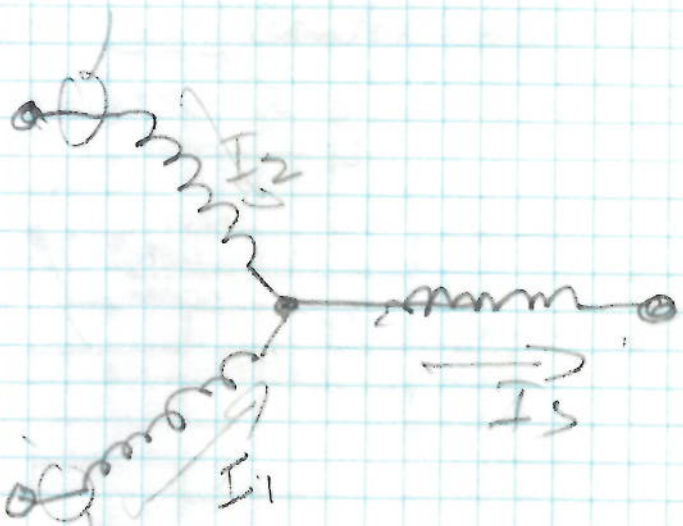
VR2 shorted (.2Ω)

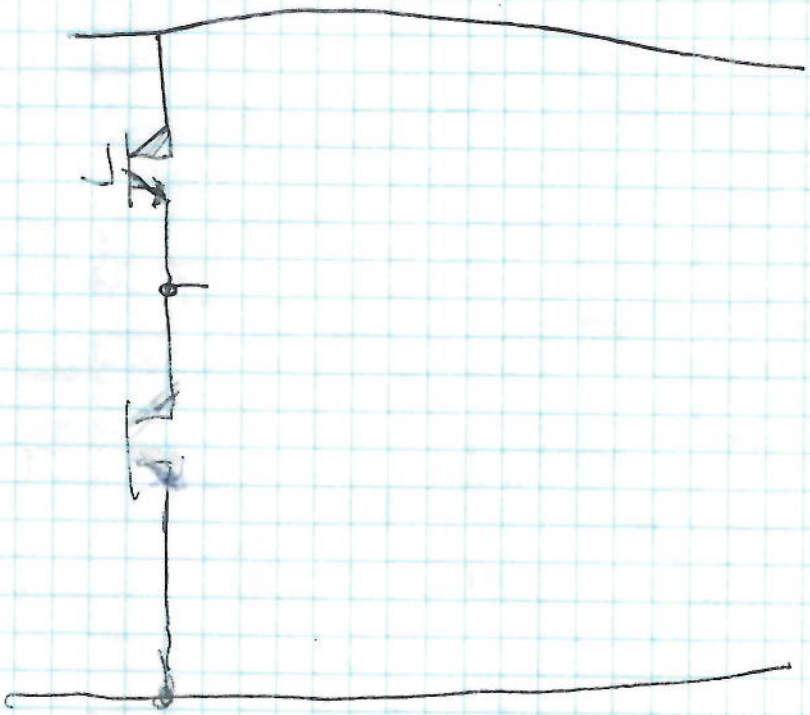
VR3 Shorted (.4Ω)

VR4 shorted (.6Ω)

VR5 2700 Ω

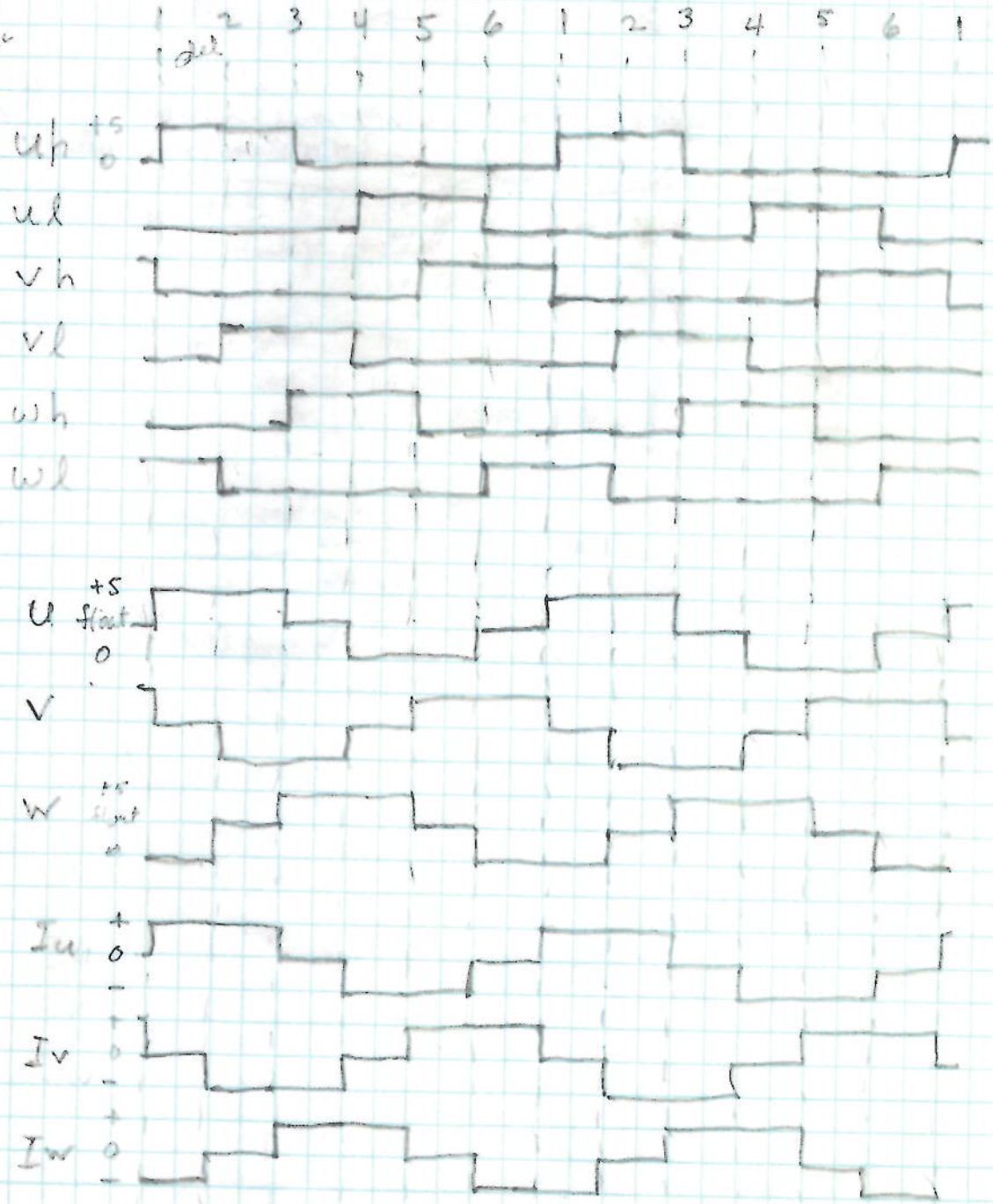
VR6 Shorted 1.2


I_2
I_3
I_1



SixStepSketch.C © 2009 Will Brunner

code.google.com/p/threephase



Audi TT ECU Replacement

		Price	Ship	Warranty/ Return
✓	innovative-autosports 99.6% Renton WA	$239.95	0	Lifetime 14 days
	14 day money back return buyers choice			
2avail	go freak 187 100% fully tested in Ohio	$295.00	0	14
X	mini-gene 99.5% 25% restock + ship cost or same 181HP (AWP)	$144.99	0	120/30
	greenlightusedautoparts working knock or replacement on vehicle	$200	0	30/30 sellers opt. in CA
X	209motorsports 97.4% "tested"	$105	0	no returns

CD 4013 Dual "D" FF

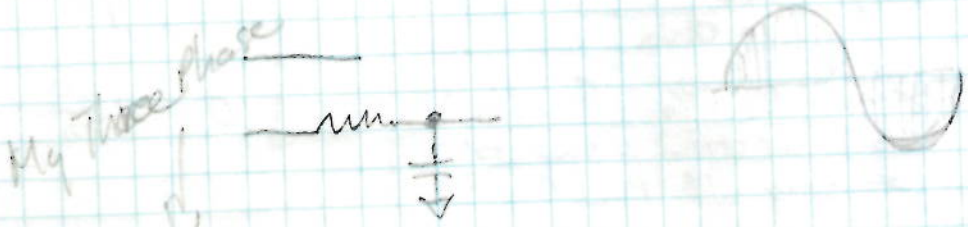
CD 4016 Quad Bilateral switch

CD 4049 Hex Inv. Buffer

CD 40106 BE Hex Schmidt Trigger, Inv

CD 4081 BE Quad 2 in AND

CD 4093 BE Quad 2 in NAND Schmitt Trigger



Max Freq @ 1 period/step

Minimum Pulse Width

@ 31.25 kHz, 32 μsec period, 8 bit, $\frac{1}{255} \cdot 32\ \mu sec = 125\ n sec$

@ 3.906 kHz, 256 μsec period, 8 bit, $\frac{1}{255} \cdot 256 = 1\ \mu sec$

Freq	steps 48	24	12	
31.25	651	325	162	Hz
3.906	81	40	20	Hz

w/ motorDelay = 1 and using millis and portState divisor = 100

48 steps set max sine freq = 20.4 Hz

Flat out = 130 Hz

24 steps = 41 Hz

12 steps 83 Hz

8 bit, 3.9 kHz

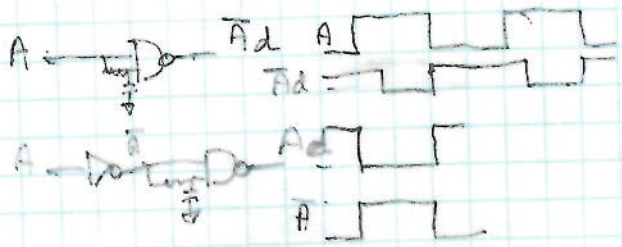
Revised program to simply delay in main loop using delayMicroseconds & mapping pot to range of:

100, 1000 → 57 μsec - 14.2 msec

17.5 Hz → 70.4 Hz

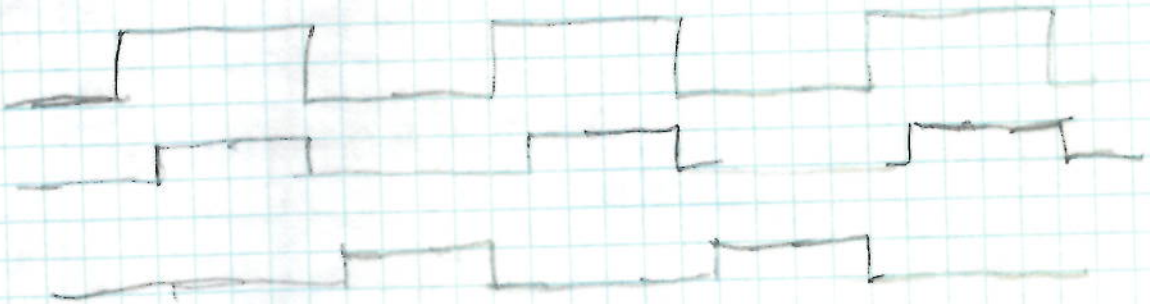
100, 2000 → 106 μsec - 14.2 msec ✓

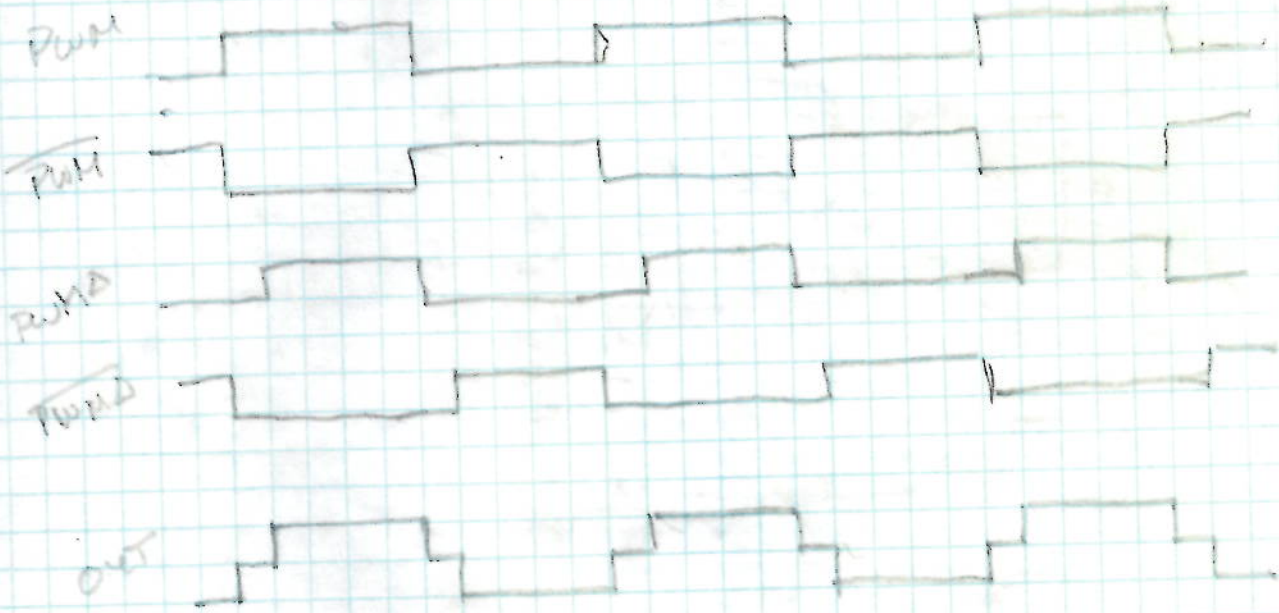
9.4 Hz → 70.4 Hz

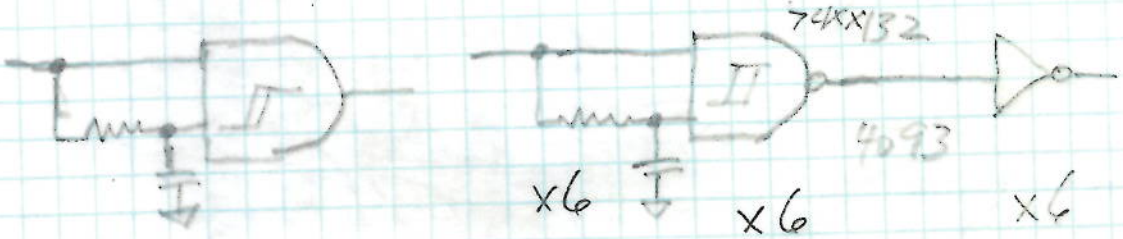


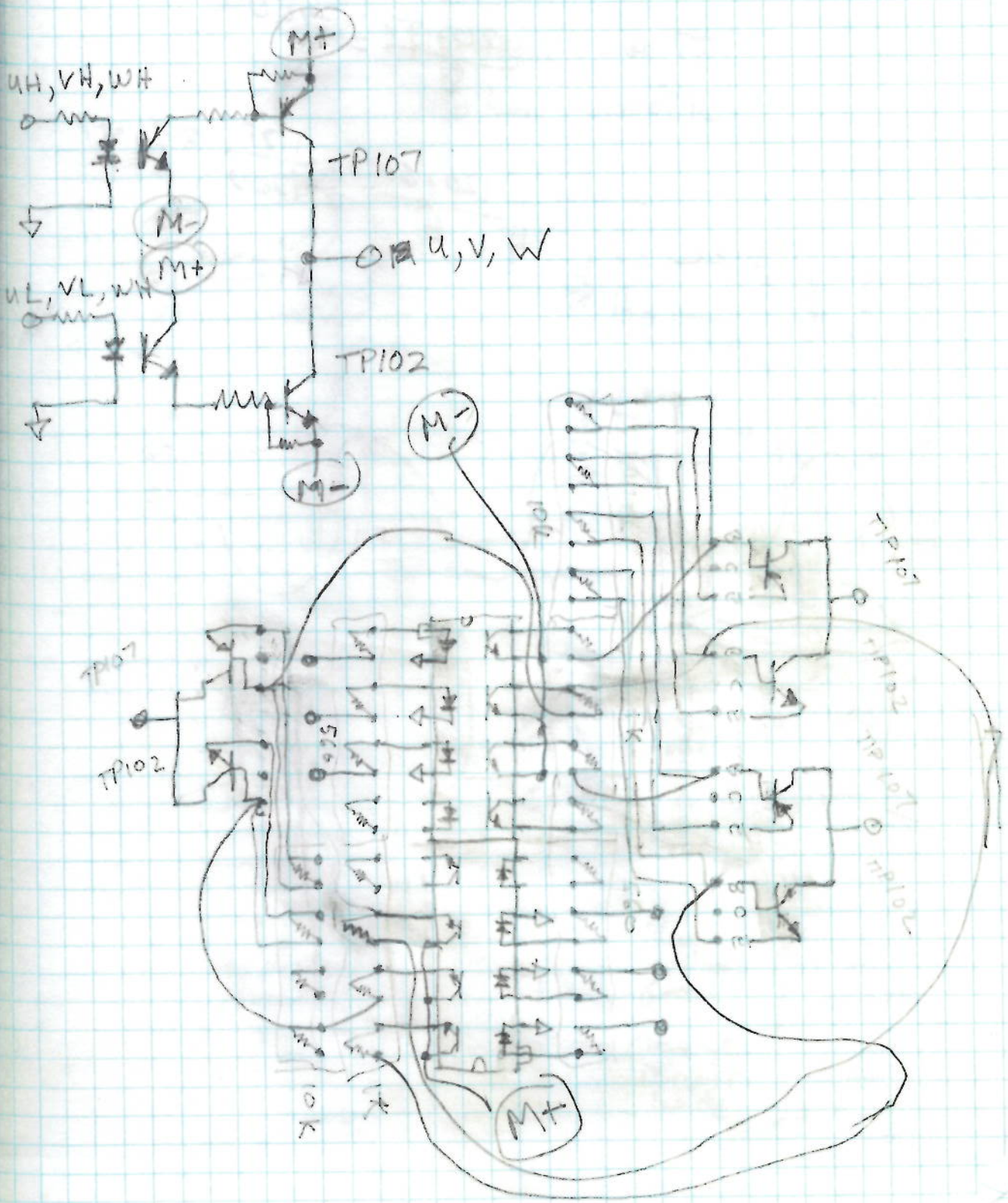
My_3threc_phase

TCCR1B 1 or 01
gives 32 μsec period
of PWM = 31,250 Hz
next choice 1 or 02
gives 3,906 Hz







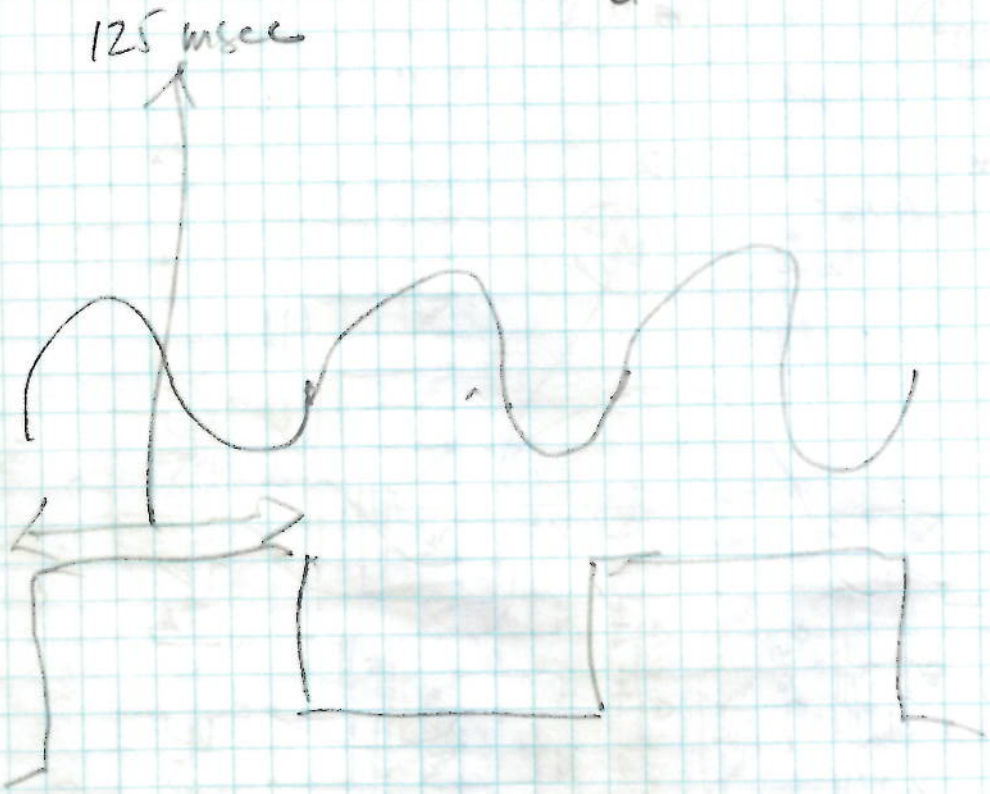

M+
UH, VH, WH
TP107
M-
M+
U, V, W
UL, VL, WH
TP102
M-
M-
TP107
TP102
M+

1/4 horse motor is 6 pole
673 rpm @ max

37 Hz
61%

$\frac{120 \cdot 37}{6} = 740$

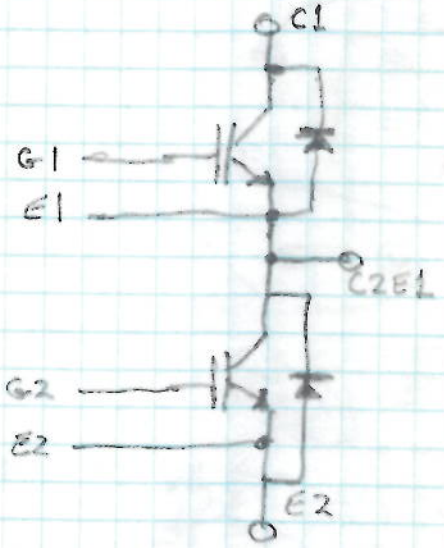
$\frac{120 \cdot 60}{6} = \frac{1175}{1200}$ 3% slip

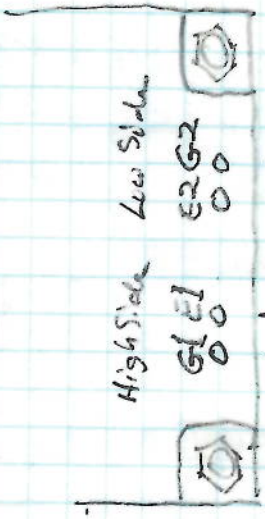


IBGT Powerex PRX

CM400DY-12H

400 Amp, 600V





1K P = $\frac{V^2}{R}$ = .625 W

I = V/R = 25mA

10K = .06 0.25

Arduino Breadboard

Green	Blue
Blue	Yellow
Violet	Green
Grey	Orange
White	Brown
Black	Red

DSP Board

Resolver -

Kearfott 05088-CH0636207 1

7 pin connector

?? - Similar Unit

S1 Red — Green/BLK

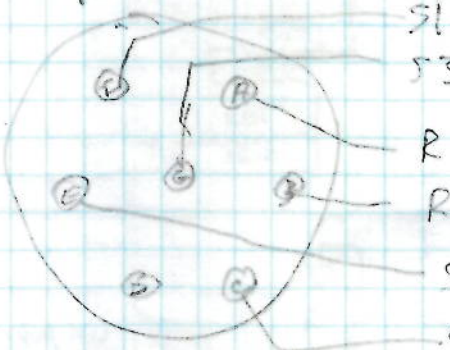
S3 BLK — Orange/BLK

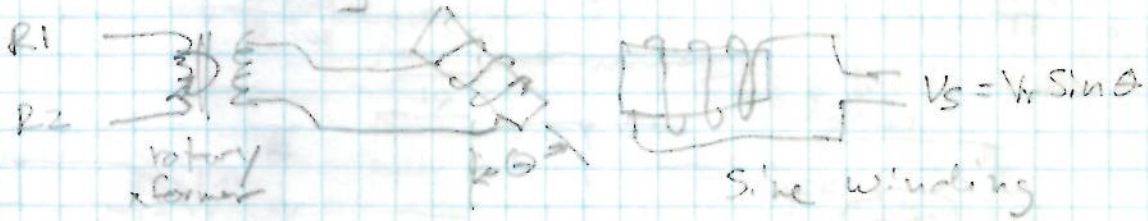
R1 Red/Wht — Red 24Ω

R2 BLK/Wht — Black

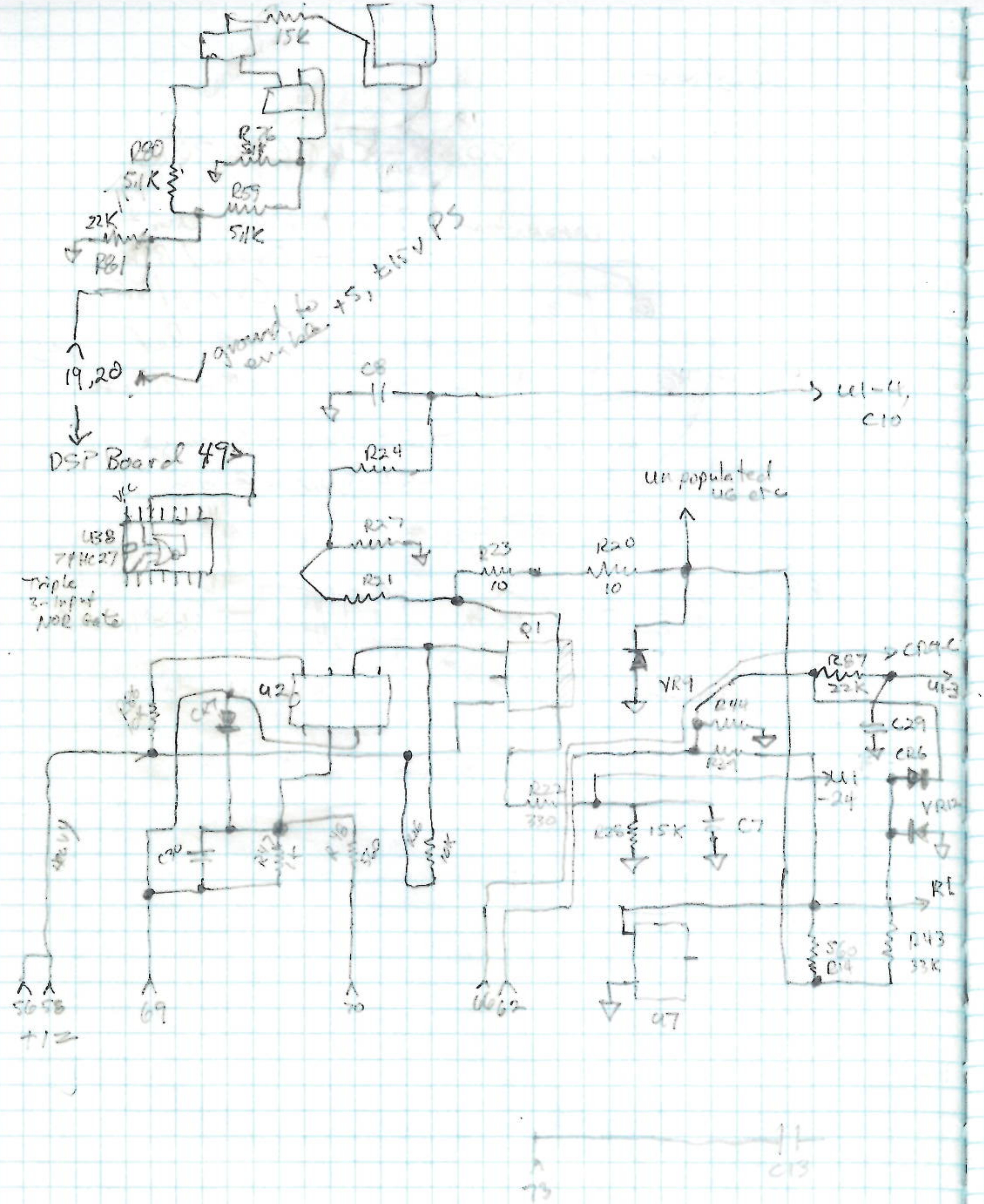
S2 Yel — Orange

S4 Blue — Green





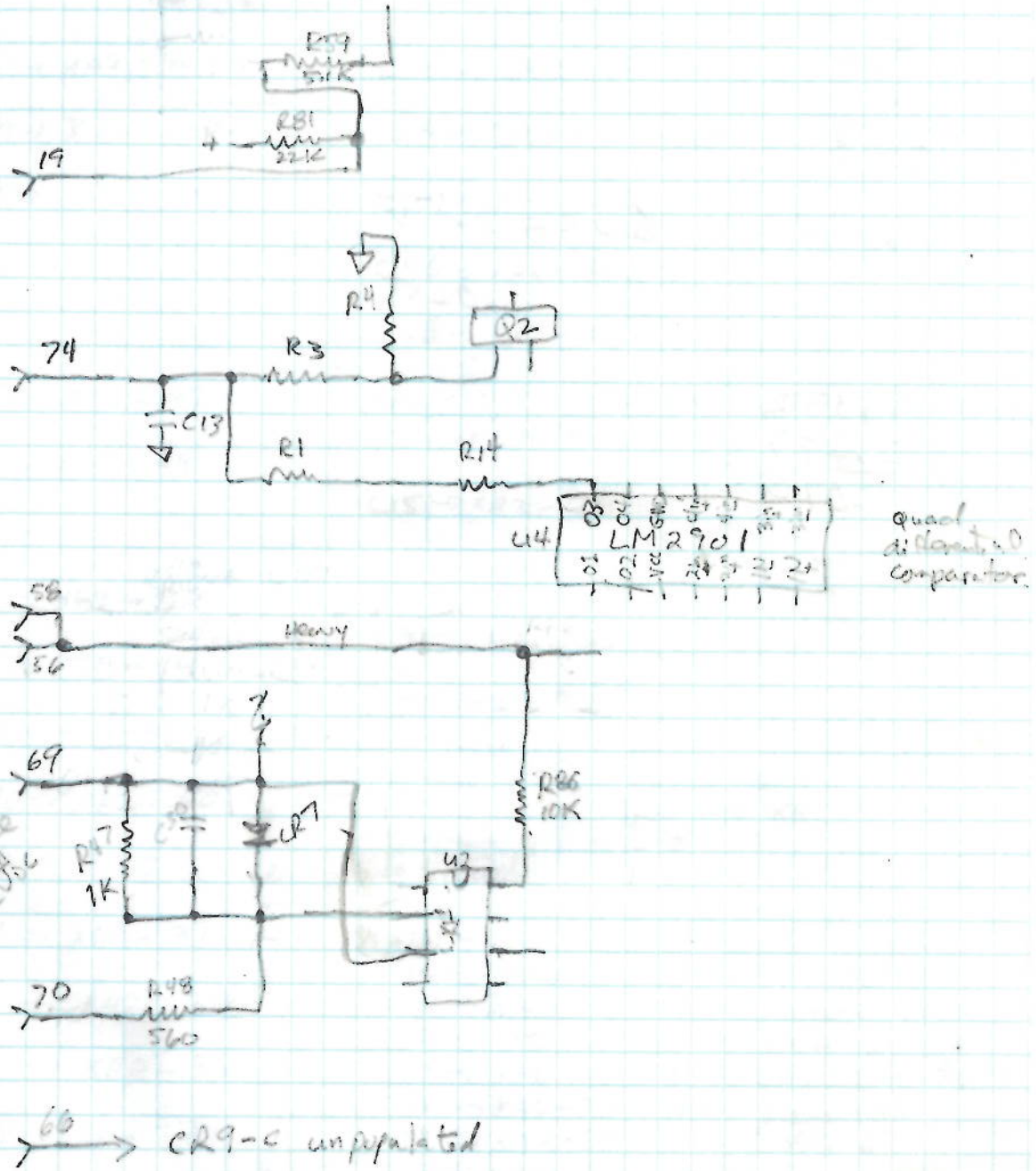
$\sin\phi/\cos\phi = \tan\theta$



15K
R76
R80
51K
R59
51K
22K
R81
19,20
ground to enable +5, ±15v PS
DSP Board 49
C8
U1-4, C10
R24
unpopulated U6 etc
R27
R23
10
R20
10
R21
U38
74HC27
Triple 3-input NOR Gate
Q1
Q2
VR9
R87
22K
CR9C
U1-3
R44
C29
R39
CR6
U1-24
VR12
R22
330
R28
15K
C7
C30
R42
R46
10K
RL
R43
33K
R14
560
Q7
56
58
+12
69
70
U6
62
73
C13

Power Control Board

P1 - 76 pin To Main Socket: P1 - 61, 64, 69, 70



$E = IR$ $P = IE$

$P = I \cdot IR$

$P = I^2R$

DSP Board connector

TE Connectivity 6-532955-6

56-6

522
.483
.039

.04 V

600 A → 2.5 V

6. .025

2.552
2.477
.075

XA1, XA2, XA3
#1 on left, even up
J1 #1 on top

Interconnect backplane

- XA3 Numbers Right
- XA1, XA2 numbers Wrong
Pin #1 on right!

Not Found C51, C10, C34, C21, C38, C22, C39, C23, C58, C59
C43, C45, C29, C49, C31, C18

C52 → XA2-90

C19 → XA3-70 -
C35 → XA3-64?
C20 → XA3-69 -
C36 → XA3-61?

C53 → XA2-87

C37 → XA2-44

C54 → XA2-93

C12 → XA2-85

C55 → J1-14

C56 → XA2-91

C40 → XA2-50

C57 → J1-5 and backplane ground

C41 → XA2-37

C24 → XA2-28

C42 → XA2-36

C25 → XA2-74

C60 → XA2-79

C44 → XA2-47

C8 → J1-9, Fan+

C27 → XA2-25

C46 → XA2-41, J1-15

C28 → XA2-17

C14, C17, C16, C48, C32 → XA3 Return
(2 pins w/o trace)

C15 → XA2-78

C9 → XA2-49

C30 → XA2-20

C50 → XA2-92

J1-16 - ?
17 → Return
18 → Return
19 → +12
20 → +12
21 → XA2-28
22 → XA2-38
23 → XA2-56
24 → XA2-77
25 → XA2-75

J1-1 → XA1-76, HV+
2 - nc
3 → XA1-72, HV-
4 - nc
5 → C57, Backplane Ground
6 → XA1-21, chassis
7 → Return, chassis
8 → Return, Fan-
9 → C8, Fan+, J1-9
10 → Return
11 - ? XA2-67
12 → +15
13 → XA2-10
14 → C55
15 → C46, XA2-41

Motor Test –

1/4 HP motor, Arduino

w/ maxFreq = 120, get 21 msec 47.6 Hz

w/ " " = 180, get 18 msec 55.5 Hz

w/ " " = 200, get 17.6 msec 56.8 Hz

300, get 16 msec 62.5 Hz.

Big Motor

@34.8 msec 28.7 Hz 830 rpm @ motor?

185 in Diam

w/ 2" tach wheel

600 rpm = 65 rpm at wheel in 1st gear

3.4 final drive

3.78 1st gear 12.8:1

$$830 = \frac{120 \cdot 30}{N}$$

$$\frac{1280}{360}$$

8:1

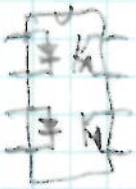
830

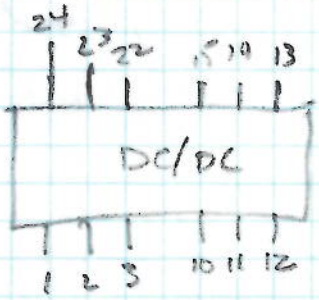
4.15 poles

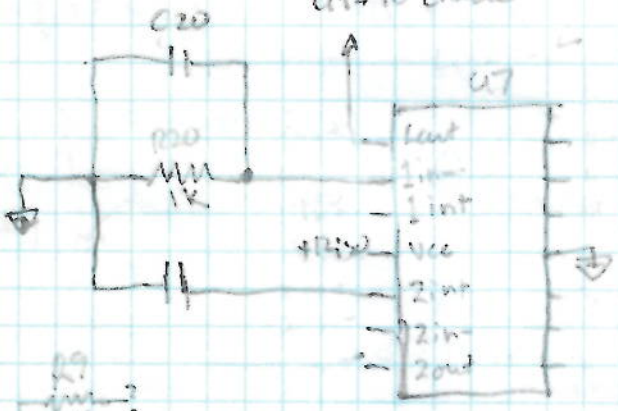
$$Hz = \frac{\# \ (5000) \cdot 9}{120}$$

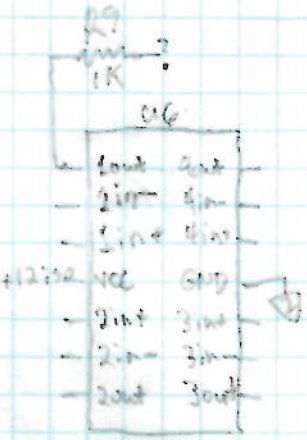
$$= 167 Hz.$$

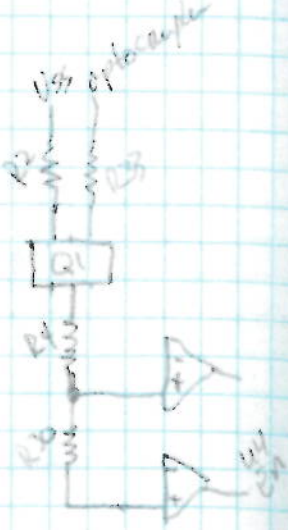
TLP621-2



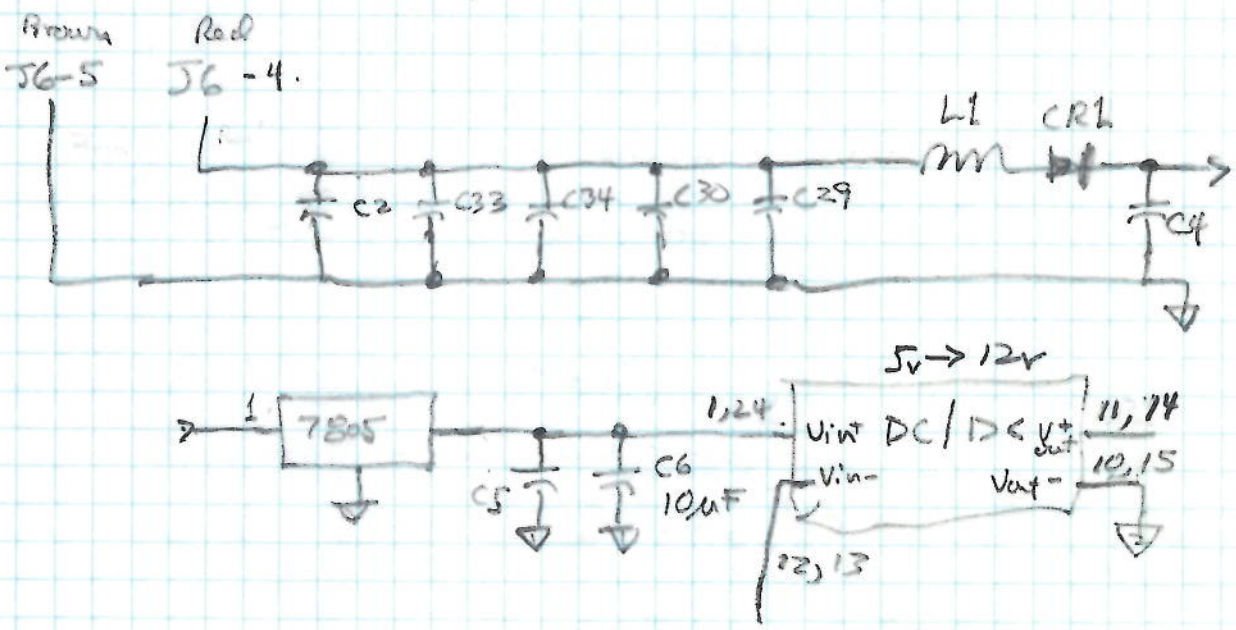


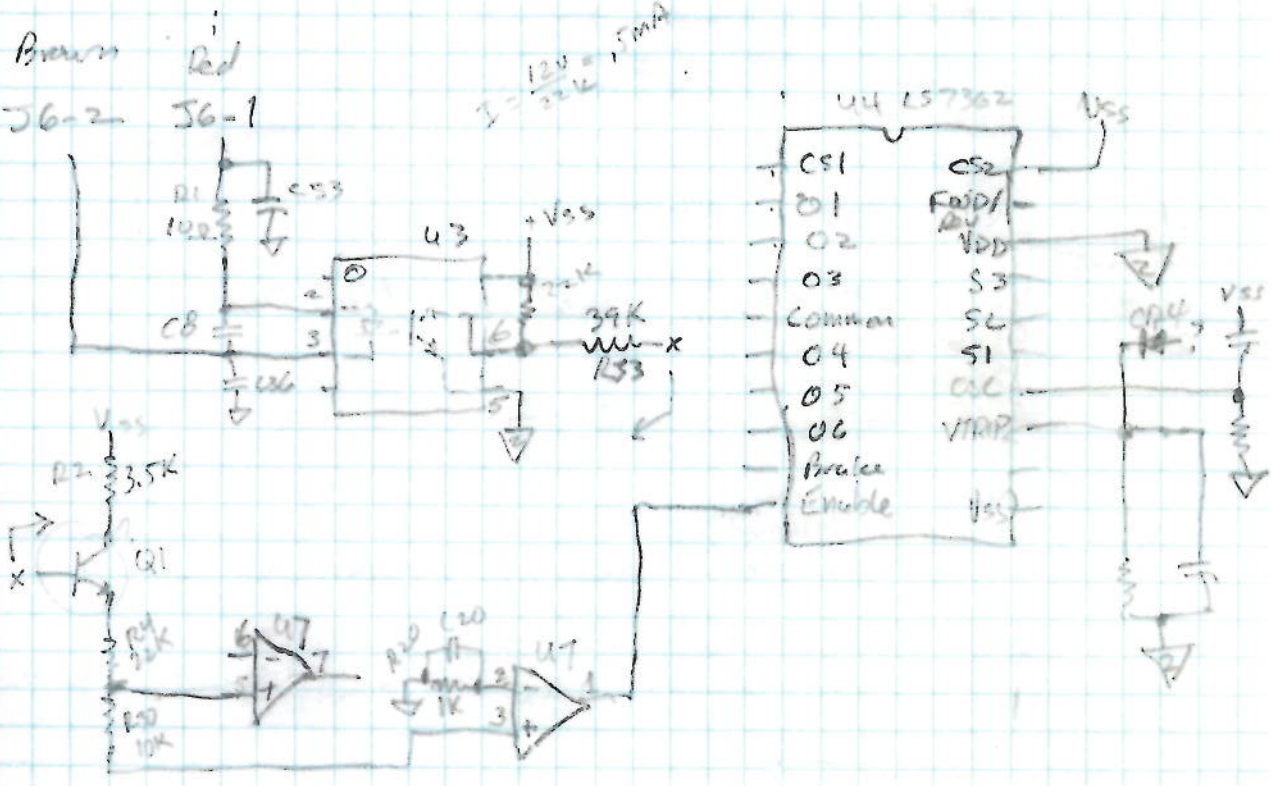






Cooling Pump Controller





U7 = LM2902 - Quad Op Amp

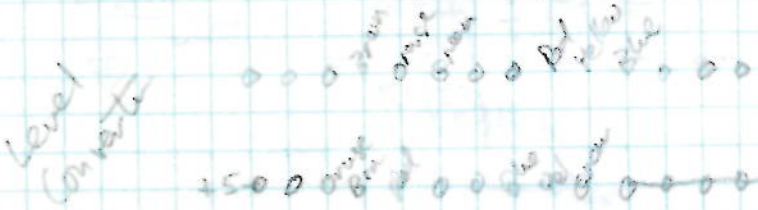
Buttons

Violet	0 → 9	top	BUTTON 1	J6-50	Step Page
Blue	1 → 10			J6-51	Select Page
Green	2 → 11			J6-52	Set Page
	3 → 12	bottom	BUTTON 4	J6-53	

Hello Arduino
12 chars + command = 14

SCL = 14 usec 50% duty cycle ≈ 71.5 kHz

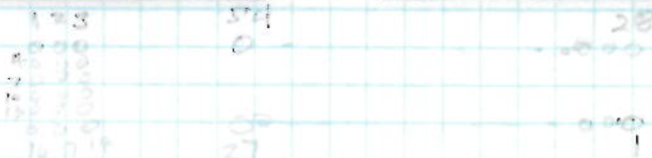
→ NXP Wood Chanted Version



level shift

Pin #	NXP	DSP Brd	Level Shift Pin out
21	Brn	Org	3
20	Org	Brown	4
19	Green	Red	5
16	Red	Blue	8
15	Yellow	Yellow	9
14	Blue	Green	10

Upside Down
Pin Locations



LCD Display

Pony's

			Pony's	
1 - RST		- Blue	Violet	J6-4
2 - SCL		- Yellow	Gray	J6-26
3 - SDA		- White	Violet	J6-25
4 - VSS	- GND	- Green	Green	J6-54, 1
5 - VDD	- +3.3	- Orange	Gray	J6-28

6 - VOUT - Cap to VSS or VDD
7 ⌐
8 └ CAP

I2C0

PIO0.27	SDA	J6-25
PIO0.28	SCL	J6-26

NXP Connections

per drawing

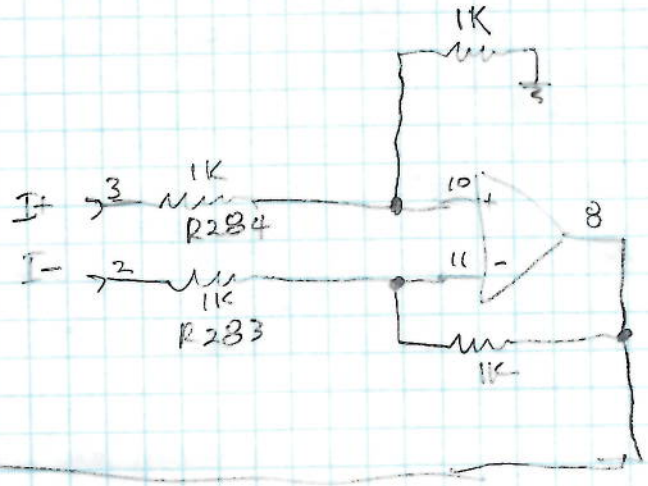
	Pulse Out @ zero	"Side"	NXP	DSP Brd
MC0A - PAD 2	Mostly Hi	Low	Brn	Or
MC0B - PAD 5	" Lo	High	Red	Blu
MC1A - PAD 8	Mostly Hi	Low	Org	Brown
MC1B - PAD 9	Mostly Lo	High	Yellow	Yellow
MC2A - PAD 11	Mostly Hi	Low	Green	Red
MC2B - PAD 12	" Lo	High	Blue	Green

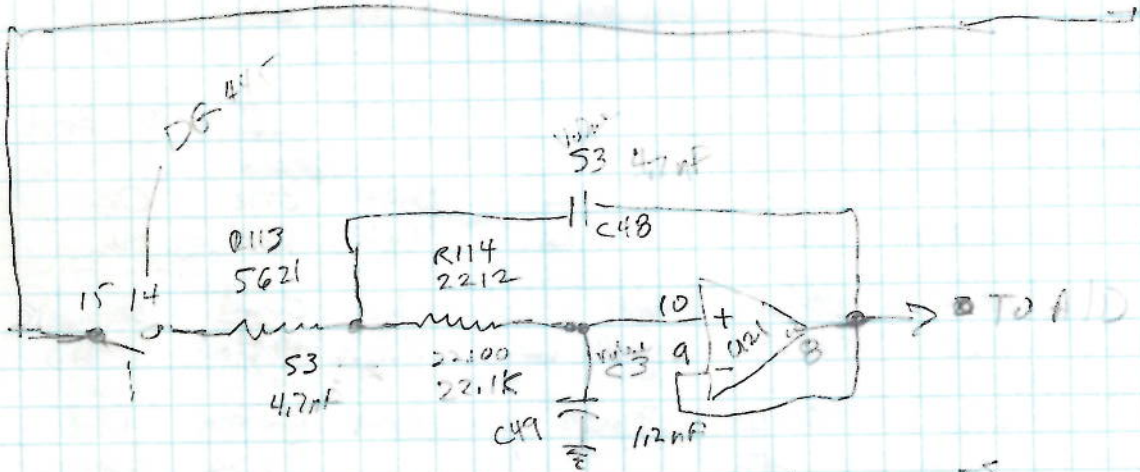
Resolver Standard Color Code

	R/W - Exc+	Red Cos+	Yellow Sin+
Blk/Y ← or	Blk/W - Exc-	Black Cos-	Blue Sin-

w = a.

New A/D MCP3008 10 b.+
3208 12 b.+





$2.2 \times 10^{3} \times 1.2 \times 10^{-8} = 2.6 \times 10^{-5}$

$= 26\ \mu sec$

$\approx 40\ kHz$

Current Sensors

LEM - HAL600 - S/SP2 (5 written above the S) ±15V in

±4V out ⟺ ±600A

on Pin 3

Pin 4 ⏚

Voltage Sensor

LEM LV 20-P

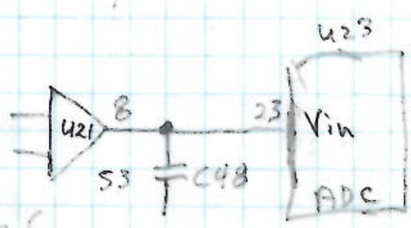
Alternate I sensor LEM HASS 600 5V

HAS 600 ±15V

Current Sensor Plug

Pin (wrt board etch)

1
2
3
4
5 +5
6 GND
7

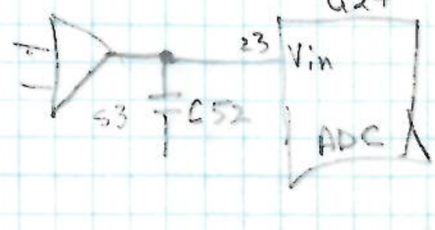


53 = 4.7nf

4.7x10⁻⁹

.0047 μF

4700 pF



	Volts	A	±15 PS only
per marking	2.490	0	
	2.511	5	+0.02
	2.591	25.6 A	
Reverse	2.470	5	-0.02

0.04V/10 Amps.

4mV/amp × 14.2

.0568 V rms

.159 V p-p

4mV/amp × 300amp = 1200 mv = 1.2V

	2.59	2.5
	+ 1.2	− 1.2
+300A →	3.7V	1.3V
0		
−300A →		1.3V

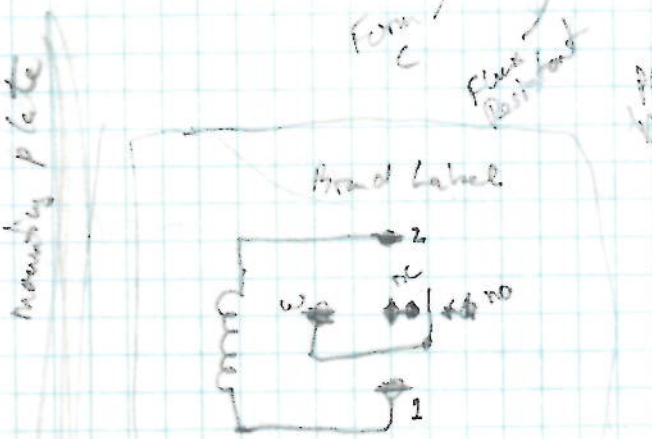
T108

10 layers pc

Aromat Relay

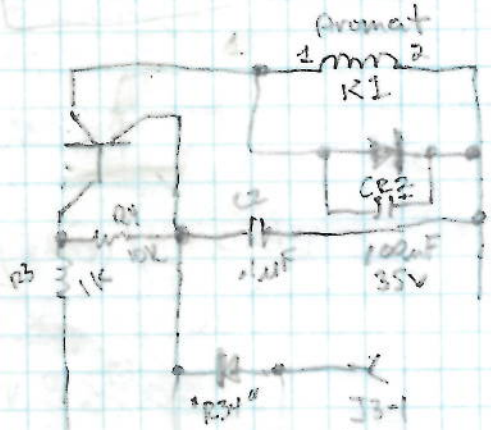
C B 1 f - P - 12V

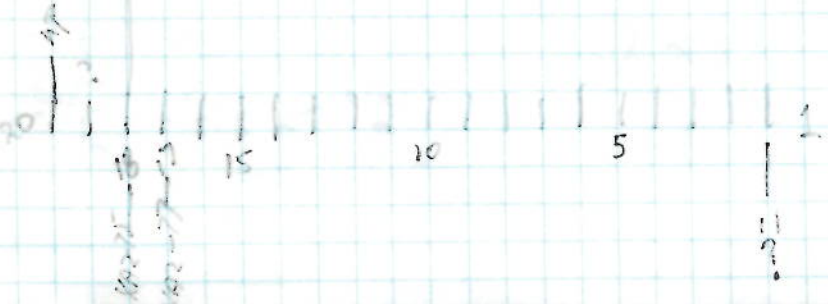
Form C — Front Panel — PC board — Coil



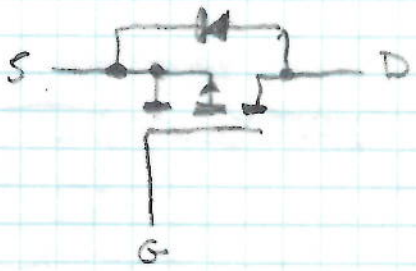
J3 - switch on face panel

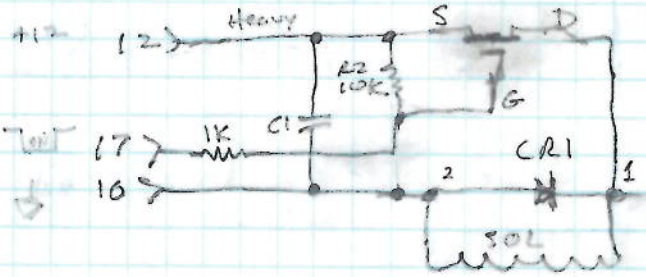
J2 - Main HV battery (like an connector?)

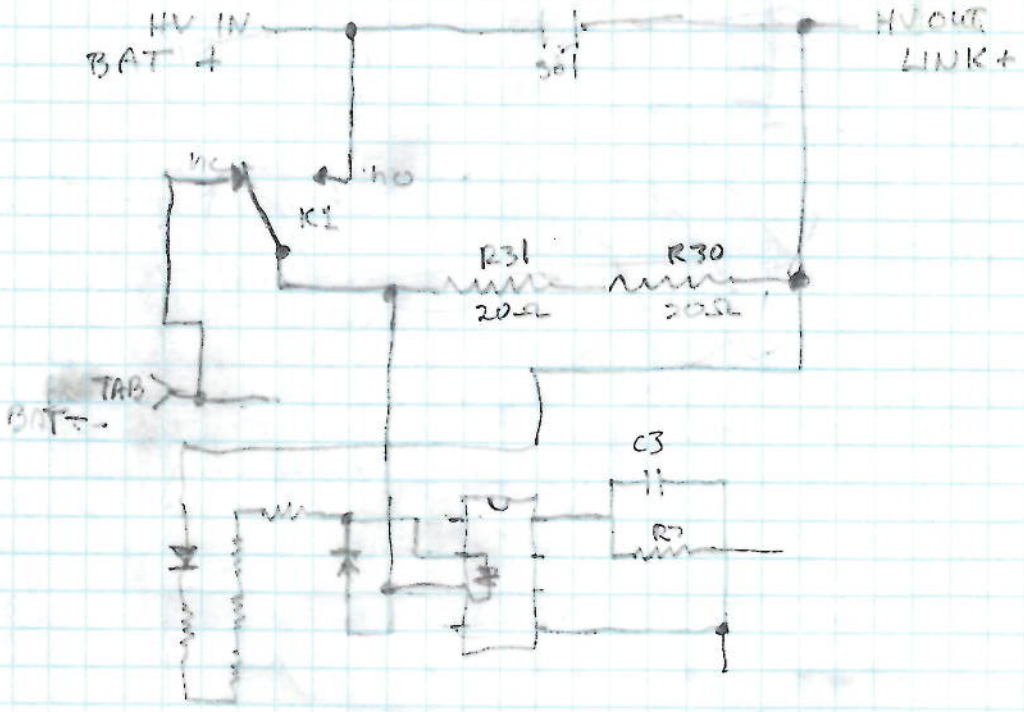


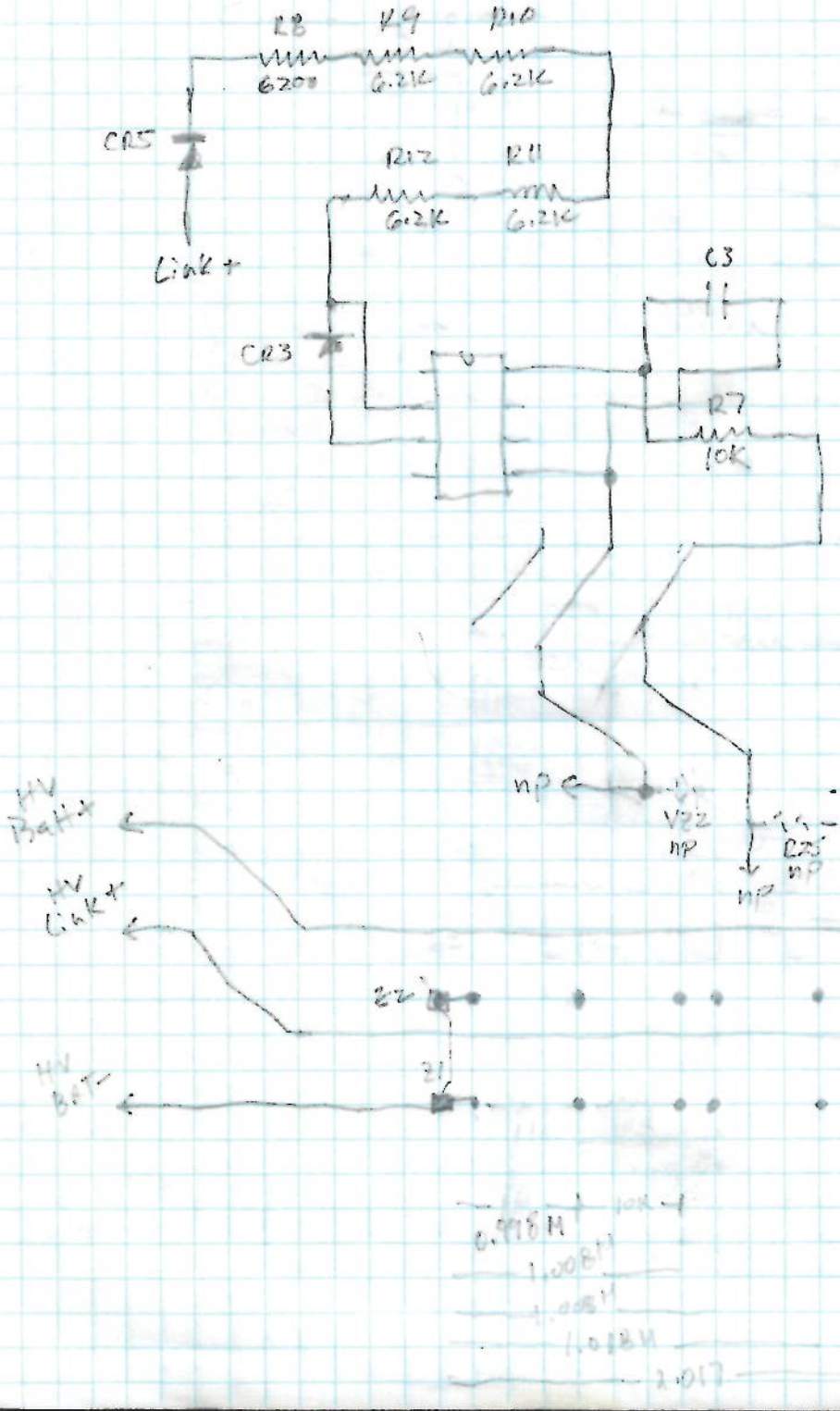


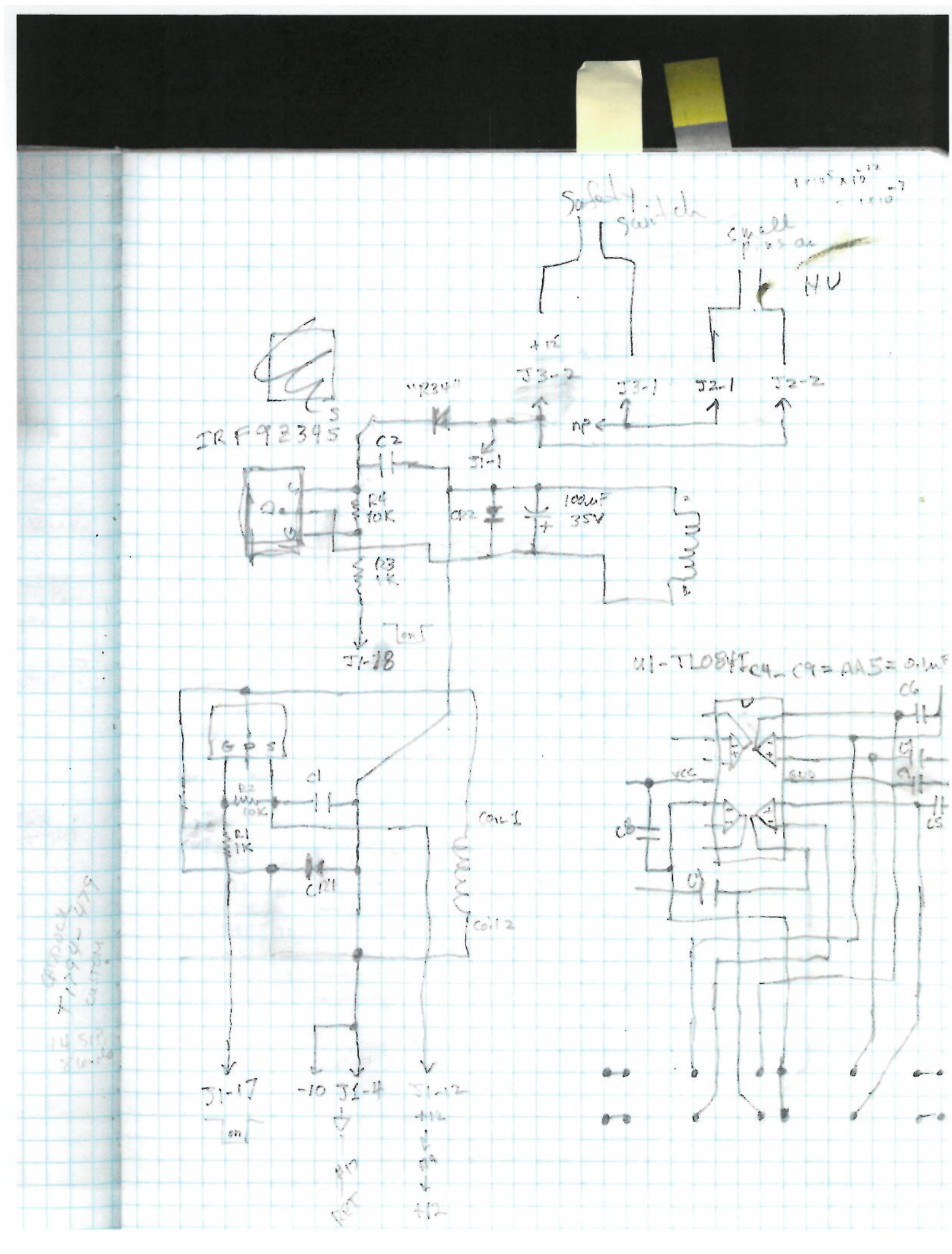
Solenoid Board



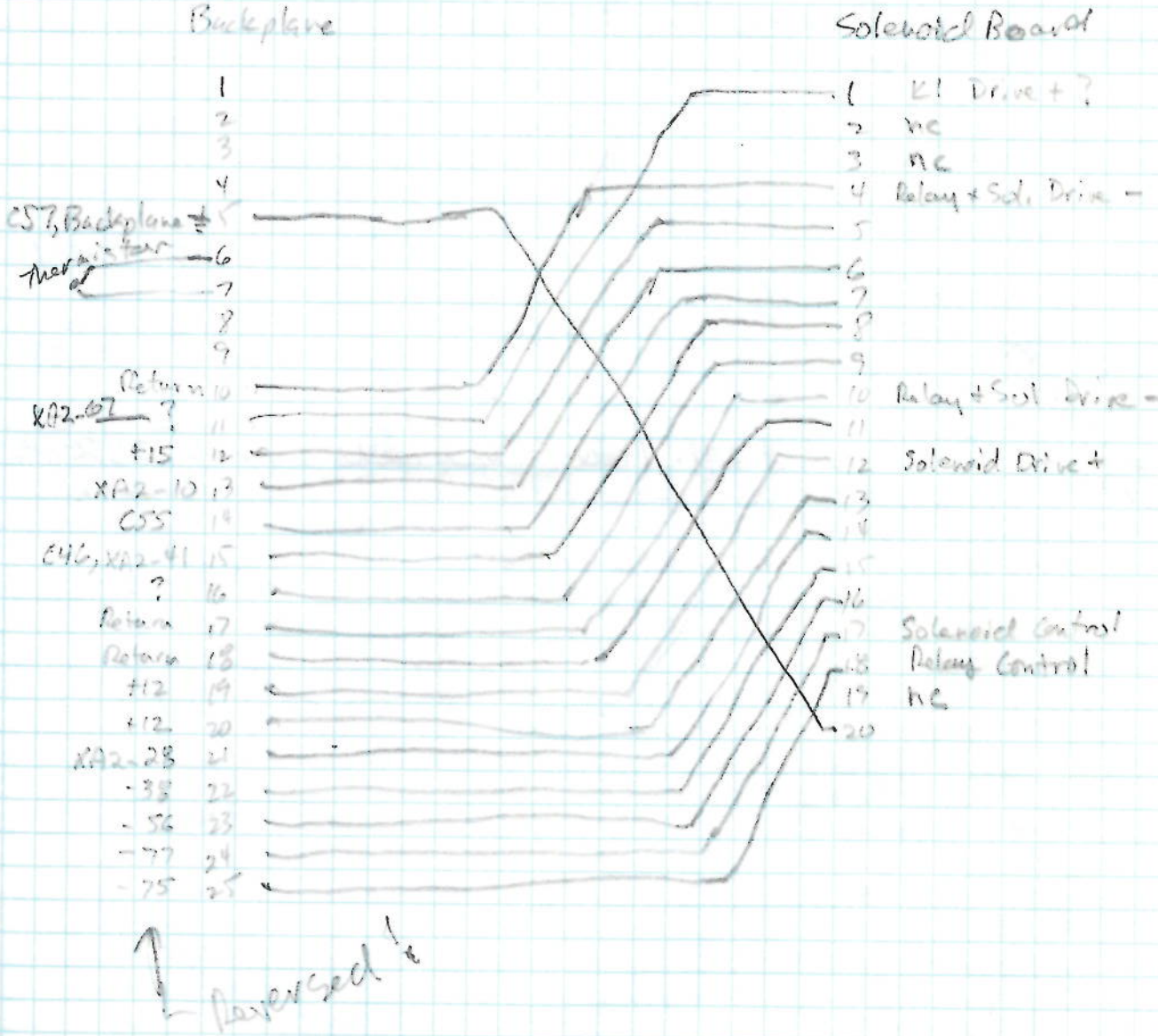


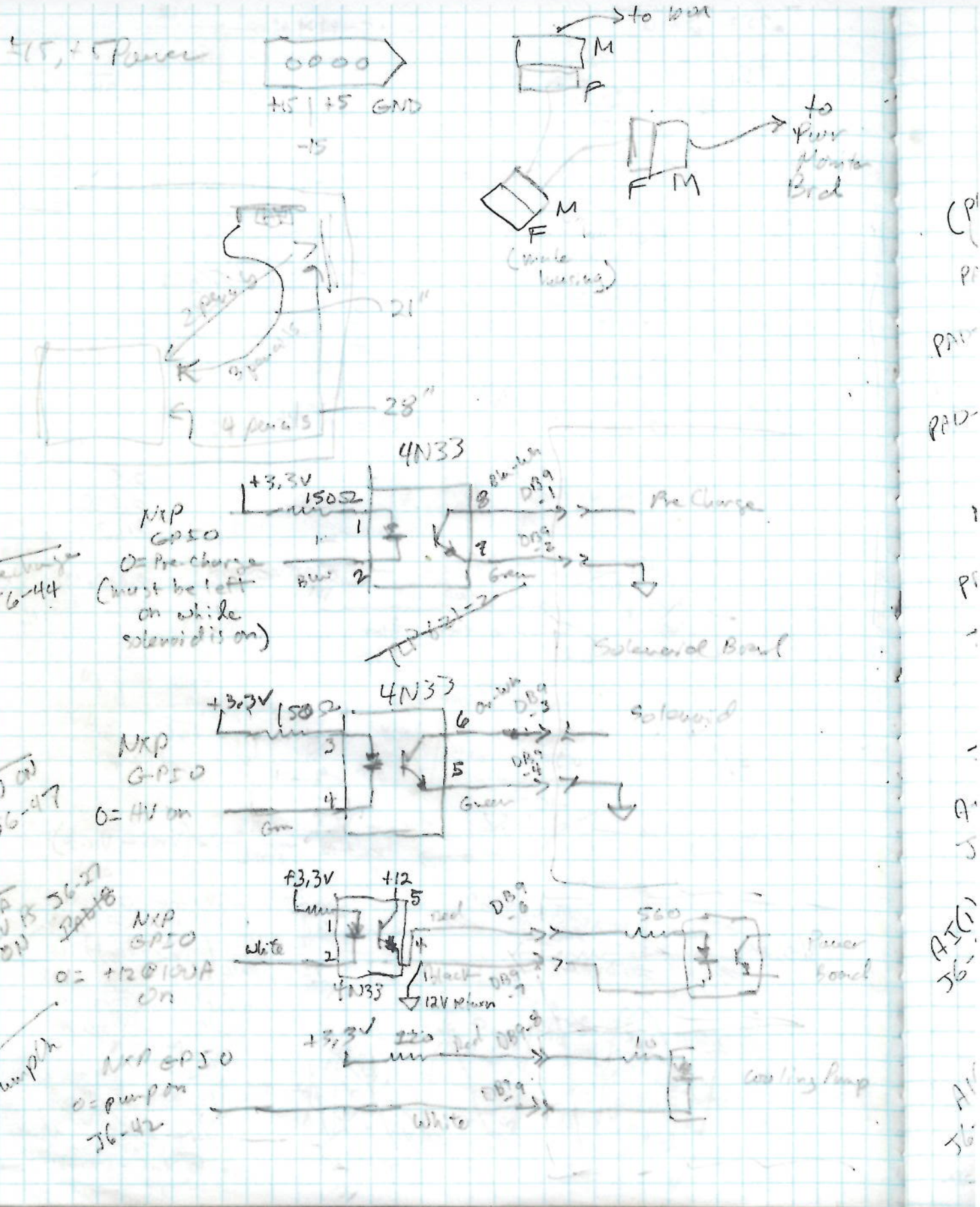



R8
620Ω
R9
6.21K
D10
6.21K
CR5
Link +
R12
6.2K
R11
6.21K
C3
CR3
R7
10K
npc
V82
np
C25
np
np
HV Batt+
HV Link+
HV Batt-
82
21


Safety switch
+12
J3-2
J3-1
J2-1
J2-2
"R34"
IRF9Z34S
C2
J1-1
R4 10K
D2
100uF 35V
R3 1K
J1-18
U1-TL084I
C4-C9=AA5=0.1uF
C6
VCC
GND
C8
C5
R2 10K
R1 1K
C1
D1
coil 1
coil 2
J1-17
-10
J1-4
J1-12
+12
RET

Solenoid Board to Backplane cable




+5, -5 Power
+5 | +5 GND
-5
to Pwr
M
P
F M
to Pwr Monitor Brd
F M
(Male housing)
21"
28"
4N33
+3.3V
150Ω
NXP GPIO
0= Pre-charge (must be left on while solenoid is on)
Pre-charge
J6-44
Pre Charge
Solenoid Board
4N33
+3.3V
150Ω
NXP GPIO
0= HV on
HV on
J6-47
Solenoid
+3,3V
+12
4N33
12V return
560
Power board
NXP GPIO
0= +12@100mA on
Pump pwr
NXP GPIO
0= pump on
J6-42
Cooling Pump
White

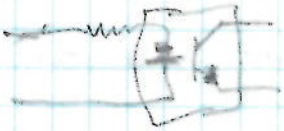
Opto

to Pwr Monitor Brd

NKP control of Power Circuits, Interlocks

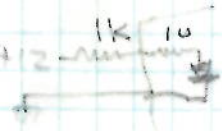
(PD,19) (PAD-17) +5, ±15 P.S. (just a switch -) single wire to common

PAD-19 Fan → switched 12V dc or opto?

PAD-18 Comm 12 V PS →  Opto

PAD-13 GND IGBT cables on ← sense link continuity

MC I/O Fast Abort ← active low from Power Monitor Brd
PAD-14 Jump to PAD-4 P1-2

J6-42 Cooling Pump Ch → opto coupler LED = +12  or equal

J6-42 Pump Power → HVDC from fuse

J6-44 Pre charge Relay → ground J1-13 if J1-1 is +12 (11K to +12)

AI(3) J6-18 Temperature ←

J6-47 HV Solenoid → ground J1-17 if J1-12 is +12 (11K to +12)

Power Board

AI(1) J6-16 AI HV voltage ← analog 0-330 V = 0-3.3V P1-1

ng Pump

AI(2) J6-17 AI HV Current ← analog 0-330A = 0-3.3V P1-3

OPTO U3 Oil Sense ← Switch closure

10/2/13

IT WORKS !!

First test run @ 4:32pm ...

30 yards in 1st gear,
33 yards in reverse,
then up the driveway 35 yards
to parked in garage!

To Do:

1. Connect up Batt Volts + temps to NXP
2. connect up discrete I/O to NXP
   - P.S. board enable latch
   - Cooling Fan (S/W)
   - Pump 12V power on/off
   - Pump enable on/off
   - DC/DC (12V 100amp) on/off
   - Pre-charge on/off
   - Main HV on/off
   - Oil pressure on/off
3. finish temperature probe + connect to NXP

Nice charger would be 400V @ 10 amps

Charging Balance Circuit

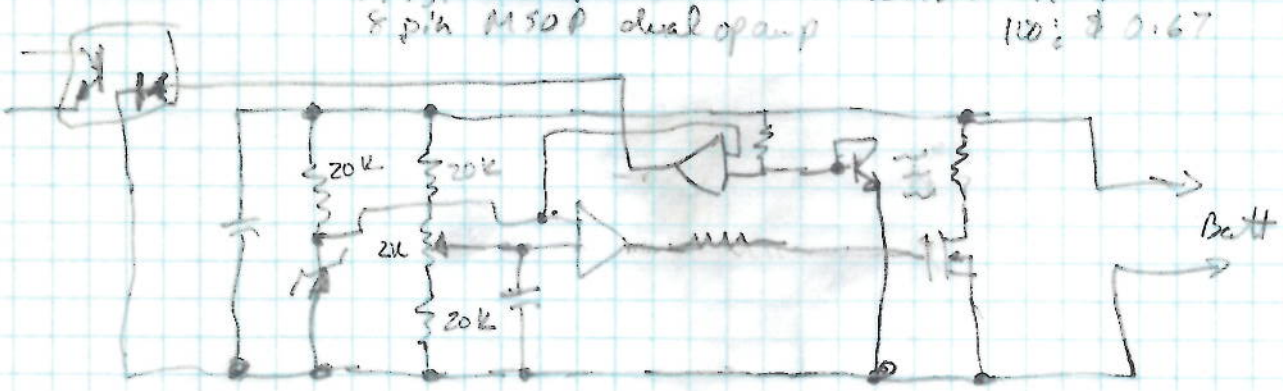
PIC12F683 based Mouser 1: $1.42
25: $1.15
100: $1.12

7	Resistors 20K, 2K, 1K, 1K, 40M, 470, 20K
1	2N2222
1	IRL520
1	LM336-2.5
1	2k pot
1	1Ω R
2	Caps 100nf · 0.1uF
1	Optocoupler (abort output)
1	LED
2	Connectors

* less resistors + caps $6.80/1
$465.80/100
$57.3/10

Analog Design

Seiko S-8943A A/B series
S-8243 BCFN-HEVTF IR Mouser 1: $0.74
8 pin MSOP dual op amp 100: $0.67



pos

IGBT Conduction loss

$$P_{cr} = v_{co} \cdot I_0 \cdot \left(\frac{1}{2\pi} + \frac{m \cos\phi}{8}\right) + r_c \cdot I_0^2 \cdot \left(\frac{1}{8} + \frac{m \cos\phi}{3\pi}\right)$$

IGBT Gate Drive

Powerex BP6A-L Series drives need 3 ~$210 ea.

PM450CLA060 450A @ 600V $450 pass in pair

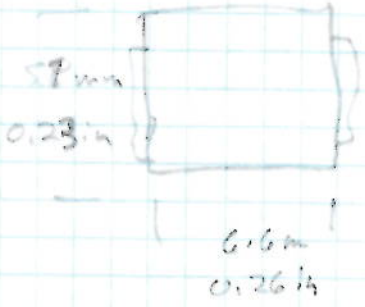
(BP6A fits on drive pins of IPM)

Powerex VLA500-01 DC/DC + gate driver $95

BP2A - dual driver - need 3

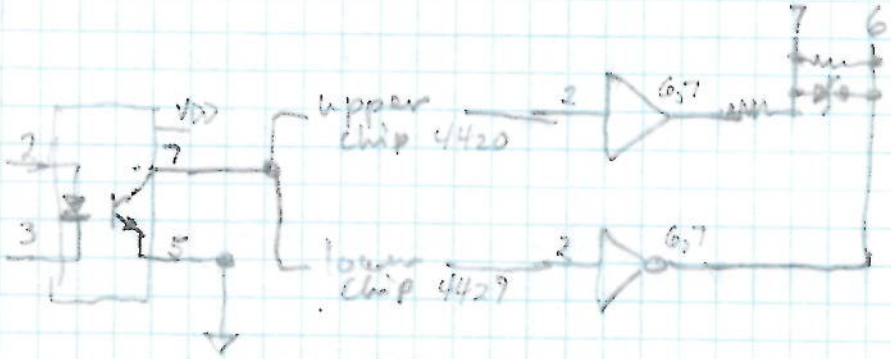
BG2B-5015 dual driver + isol. pwr 15V.

IN4745 16V Zener



6.80/1
465.80/
57.13/10

Driver: In = 2, 3
Out = 6, 7
Vdd = 1, 8
Gnd = 4, 5



I/B

1	2	3	4	5	6
✓	✓	✓	✓	✓	✓

✓

2,3
6,7
1,8
4,5

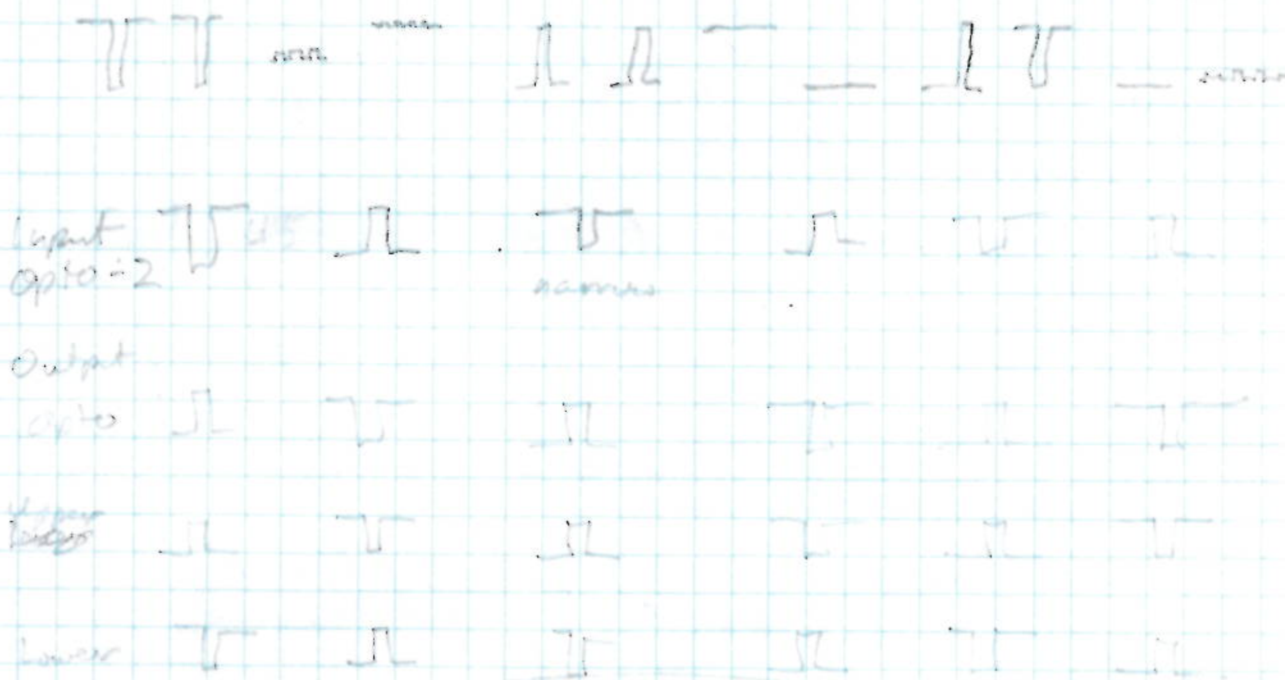
Driver Board Test 10/14/2013

	J1-7 Left Q1	Right	Lft Q2	Right	Lft Q3	Right
Opto Out # 7	L	L	L	L	L	L
Inv. Driver # 6,7	H	H	L	Lv	H	L
Non-inv. Dr. # 6,7	L	L	L?	H	L	L

① ② ③ ④ lower ⑤ ⑥ v = variable

Pulse Test

	J1				J2				J3			
upper	✗ -7	✓ -6	✗ -4	✗ -3	✓ -7	✗ -6	✗ -4	✗ -3	✓ -7	✓ -6	✗ -4	✗ -3

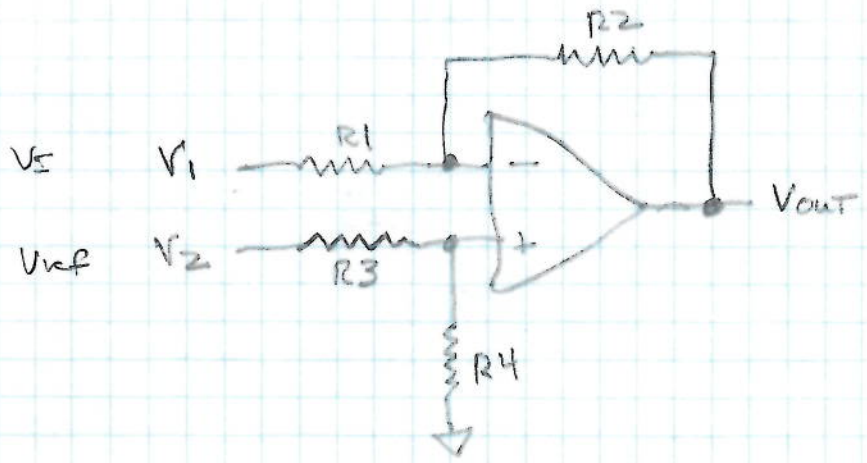


Post Repair - all opto inputs ROK
- opto output 1=OK, 2- , 3=OK, 4,5,6=OK

	1	2	3	4	5	6	
(lead) lower chip in	✓	–	✓	✓	✓	✓	after [illegible] OK
(pad) " " out	✓	–	✓	✓*	✓	✓	*gnd offset
(lead) upper chip in	✓	–	✓	✓	✓	✓	
(pad) " " out	✓	–	✓	✓	✓	✓	
D.TX	✓	✗	✓	✗	✓	✗	

$y_1 = ax_1 + b$

$y_2 = ax_2 + b$



$$V_{out} = \left(\frac{R1 + R2}{R3 + R4}\right)\frac{R4}{R1} V2 - \frac{R2}{R1} V1$$

For $R1 = R3$ & $R2 = R4$

$$V_{out} = \frac{R2}{R1}(V_2 - V1)$$

$$V_O = \left(\frac{100k + R2}{100k + R4}\right)\frac{R4}{100k} \cdot V2 - \frac{R2}{100k} \cdot V1$$

$$V_O = \frac{V2 \cdot R4 \cdot (100k + R2)}{100k \cdot (100k + R4)} - \frac{R2 \cdot V1}{100k} \cdot \frac{(100k + R2)}{(100k + R2)}$$

$$V_O = \frac{V2 \cdot R4 \cdot (100k + R2) - R2 \cdot V1 (100k + R2)}{100k \cdot (100k + R4)}$$

$$V_O \cdot 100k \cdot (100k + R4) = V2 \cdot R4 \cdot (100k + R2) - R2 \cdot V1 (100k + R2)$$

$$100k + R4 = V2 \cdot R4 \cdot (100k + R2) - R2 \cdot V1 (100k + R2)$$

$$R4 = 100k + V2 \cdot R4 (100k + R2) - R2 \cdot V1 (100k + R2)$$

$$R4 = 100K + 100k \cdot V2 \cdot R4 + V2 \cdot R4 \cdot R2 - 100k \cdot R2 \cdot V1 + R2^2 \cdot V1$$

b

2.5
.625
3.125

2.500
−.625
1.875

8920
→1175

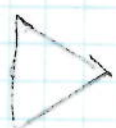
y = ax + b

2.5 ± 0.625

+400A → 3.125
0 A → 2.5
−400A → 1.875

New Circuit Test
Vref = 2.537
Vin 2.020 2.656
Vout 3.29 0.208
ΔVin +0.517V +0.119
−331A 76A 0A
w/2.5 ref

331
76
407



2.5
.517
3.017

407A

.119
2.5
3.29
−.21
2.62
3.08

.46875

.517
.625

656
537
.119
.625

0 − .625

132 AN

300	3	2.25	3.00
0	0	0	0.75
−100	−1	−0.75	0.00
−300	−3	−2.25	

640A/V

.119V

$(R1 + R2)/(R3 + R4) = 1.06$
$R4/R1 = 5$
$R2/R1 = 5$

$K(V_1 - V_2)$

$K(V_1 \begin{smallmatrix}3.125\\1.875\end{smallmatrix} - V_2)$

$\frac{3}{.625}$

1.825

4.8 (3.125 / 1.875 − 1.56)

4.8 (2.5 / 0) → 3 / 0

R4 = 5R
R2 = 5 R1

$(1.1 + 5R1) = 1.06(R3 + 5R1)$

$6R1 = 1.06R3 + 5R1$
$1.06R3 = 6R1 - 5.3R1$
$R3 = .66R1$
$R2 = 5R1$
$R4 = 5R1$

)

)
1 + R2 · V1

1.06 / 5.30

.7R1 / 1.06

Resolver to QEI 3½" x 3" x 3/8" or ½" or 1"

↓ Nu conn ↓ female conn ↓ complete conn

Connector

90 Sq. Flange Receptacle

94 Single Hole Receptacle

96 Cable Mount Plug

Durr 319

318 available

or 1"
↓
complete
conn

Large Connector

SG009-23-5351 Deutsch 11139 9628A

53 #20 Contacts Box is female

Insert 23-53

Arrow	D38999/26WA53PB	~~$54.20~~ Conn	$52.87	1
11/29/13	M39029/58-363 Din		$0.1845	57
			$63.39	
			+ Tax 3.81	
			+ Ship 8.00	
			$75.20	

Ref # IC 0-066 of 12

2N4403 PNP

1 = E
2 = B
3 = C

2N4401 NPN 60V
600mA
625 mV
hFE ~100

Small Connector

Plug - DG123AGRLL-99PL-6152

11139 9639B

1/1/14 CAN Bus Test

			MCP2551 Xceiver
CAN1	P0.0 = RD1 =	J6-9	Pin 4
	P0.1 = TD1 =	J6-10	Pin 1
CAN2	P2.7 = RD2 =	J6-49	Pin 4
	P2.8 = TD2 =	J6-50	Pin 1

RD-TD 1K Test - AOK

→ ← Busee

Self Receive Through Xceiver AOK - ⎍⎍⎍

R_s = 38K

CAN1-CAN2 loop test - AOK

Inverse Park per the paper

$V_a = V_\beta$

$V_b = \frac{1}{2}V_\beta - \frac{\sqrt{3}}{2}V_\alpha$

$V_c = -(V_a + V_b)$

$V_c = -V_\beta - \frac{1}{2}V_\beta + \frac{\sqrt{3}}{2}V_\alpha$

$= -\frac{3}{2}V_\beta + \frac{\sqrt{3}}{2}V_\alpha$

2803

per MC code

$V_a = V_\beta$

$V_b = -\frac{1}{2}V_\beta + \frac{\sqrt{3}}{2}V_\alpha$

$V_c = -\frac{1}{2}V_\beta - \frac{\sqrt{3}}{2}V_\alpha$

checks w/ ref. but α, β reversed

another ref not reversed

$2\pi = 6434$

2 • Pi << 16 / QEImax

return int16_t(tmpPos • (2π << 16) / QEI Max) >> 16

vMC_LIB_SetPWM_F6_10

AH = ((12000/2) • (1024 − A.full)) / 1024

6000 • (400) / 1024

A.full = 0 ⇒ AH = 6000

A full = 1024 ⇒ AH = 0

234

Per Paper

$AH = (\text{Period}/2) \cdot A + \frac{\text{period}}{2}$

Our V/F uses 0-900 as value to load PWM

Pulse (Period − Pulse)

Vq	Vd	100k - 10⁴ pF sinewave p-p	
10K	0	400 mV	
10K	10K	580 mV	
60K	60K	350 mV	20 − 30
60K	0	220 mV	22 − 30

Current $10^{-2} \times 10^{-6} = 10^{-8} \times 22 \times 10^{3} = 22 \times 10^{-5} = 2.2 \times 10^{-4} = 220\,\mu sec$

2.2 m sec $RC = 0.01\mu F \cdot 22K$

$10\,000 \times 10^{-12}$ 10^{-8} 22×10^{3}

$22\ 10^{-5}$

Simple FOC Test

"Fan" = PAD 19 MCABORT/ = PAD 4

10 KHz = 100 usec per execution (step)

for freq of 100 Hz period = 10 msec

10 msec ÷ 100 usec = 100 steps per cycle

need to increment ~~alpha~~ alpha by $2\pi/100$

MCOA = PAB 2
0B 5
1A = 8
1B = 9
2A = 11
2B = 12

Vd. full = 0
Vq. full = 10000

	alpha	Sector	Valph	Vbeta	Vr1	Vr2	Vr3	A	B	C
64		1	-625	9980	311	-173	-140	470	668	355
128		1	-1250	9992	310	-189	-122	478	667	356
192		1	-1865	9824	307	-204	-104	462	666	358
256		1	-2491	9688	302	-219	-85	445	664	360
320		1	-3076	9512	297	-232	-66	429	661	363
384		1	-3662	9307	290	-245	-47	410	658	366
3584	4		3516	-9365	-293	241	51	607	366	658

~~Vr not scaled~~ wrong

After new pwm routine w/ Vq = 10 000, Vd = 0
get 3 phase sine wave ~ 400 mV p-p centered 2.1V
w/ Vq = 10,000; Vd = 10,000 ~ 580 mV p-p " "

Thermister Test

0°C 32°F = 32.37 KΩ

125°F ≈ 3.07 KΩ

~~89°F ≈ ...~~ 60°F ≈ 15.13

~90°C ≈ 194°F = 720 Ω

~~42°...~~

T in °Kelvin

$$\frac{1}{T} = \frac{1}{T_0} + \frac{1}{B}\ln\left(\frac{R}{R_0}\right)$$

$T_0 = 25°C \rightarrow 298.15 K$
$R_0 = 10K$
$B = 3950$ (for Adafruit Th)

$$R = R_0 e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

for T = 0°C = 273°K

$$R = 10K \cdot e^{B\left(\frac{1}{273} - \frac{1}{298}\right)}$$

.003663 − .003356

.0003073

1.214

3.366

R = 33.7 K

for T = 52°C = 325°K (125°F)

R = 3.3 K

450Ω / 1°C

62°F = 16.7°C

2.2°C
1.7°C
8°C
450Ω × 8 = 3.6 K

1.2°C
10.2 K

More
FOC Test

5.0	+600
2.5 *	0
0	-600

$\frac{5\ V}{1200\ A} = 4.167\ mV/A$

2100

4095 counts = 285 Amps

2775 counts = 0 amps

0 counts = -600 A

So +600A = 2775 + 2775 = 5550 counts

600A / 2775 counts = 0.216 A/count; 4.625 counts/amp

4095 counts - 2775 counts = 1320 counts x 0.216 A/count

= 285 amps.

microC offset = 2775 int16
F-to-D gain = 0.216 } To produce Amps

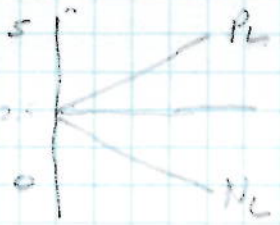
1000 RPM Test Data of 06/02

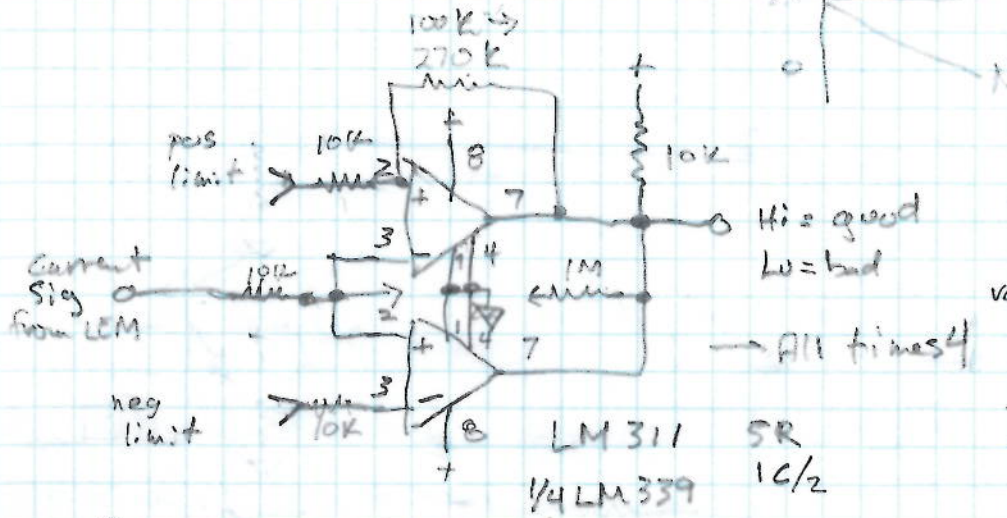
OK

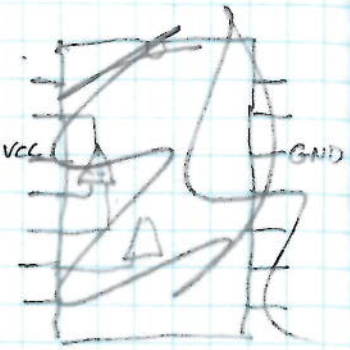
$N_L = 2.5 - (P_L - 2.5)$

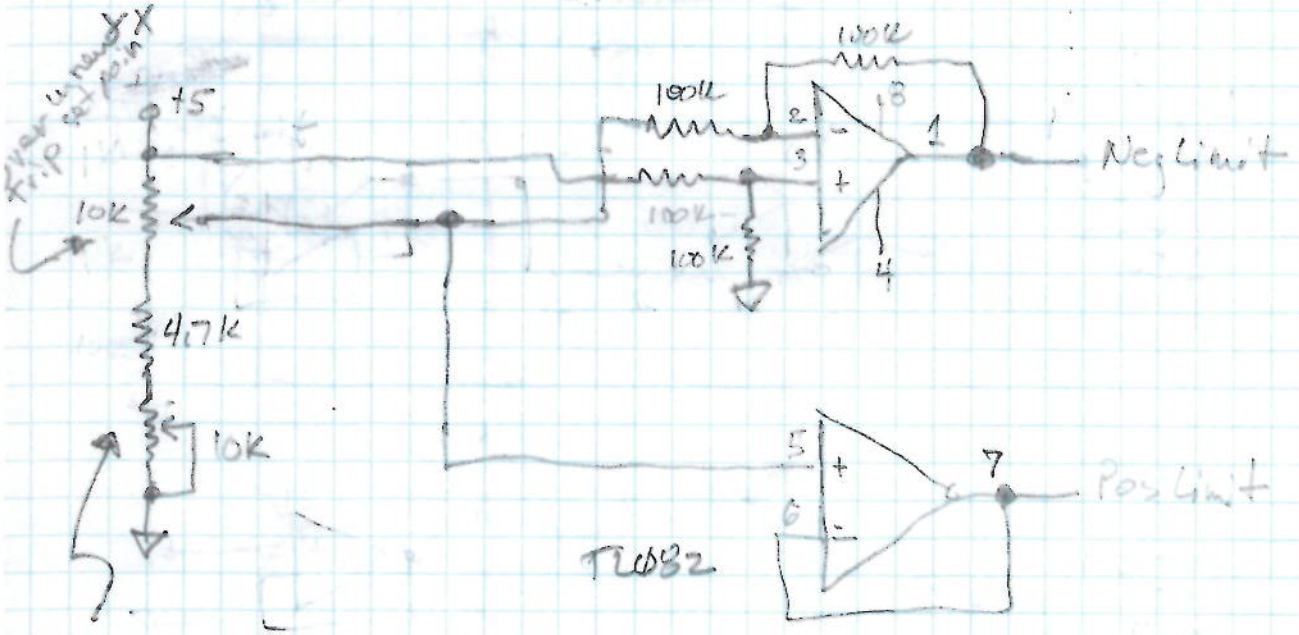
$= 2.5 - P_L + 2.5$

$= 5 - P_L$

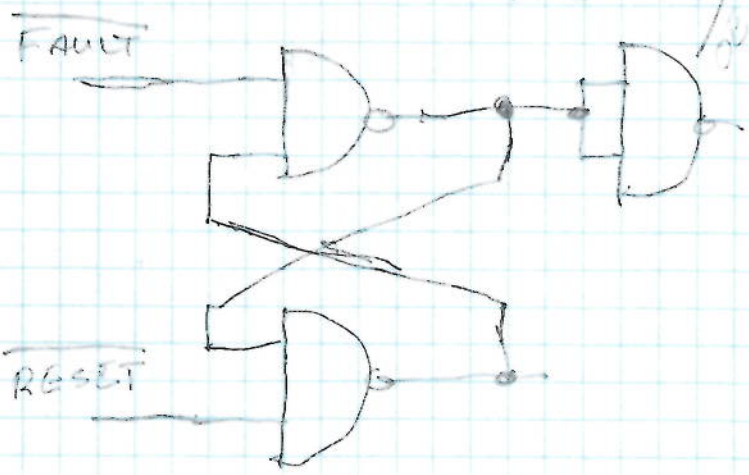


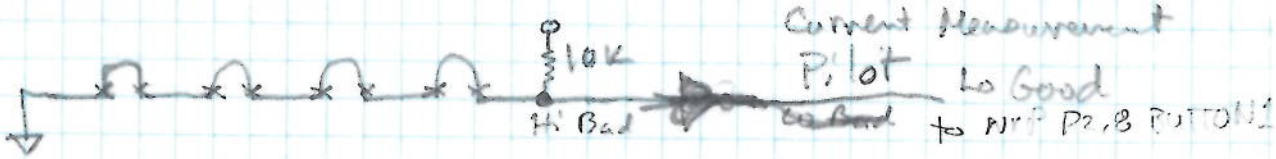




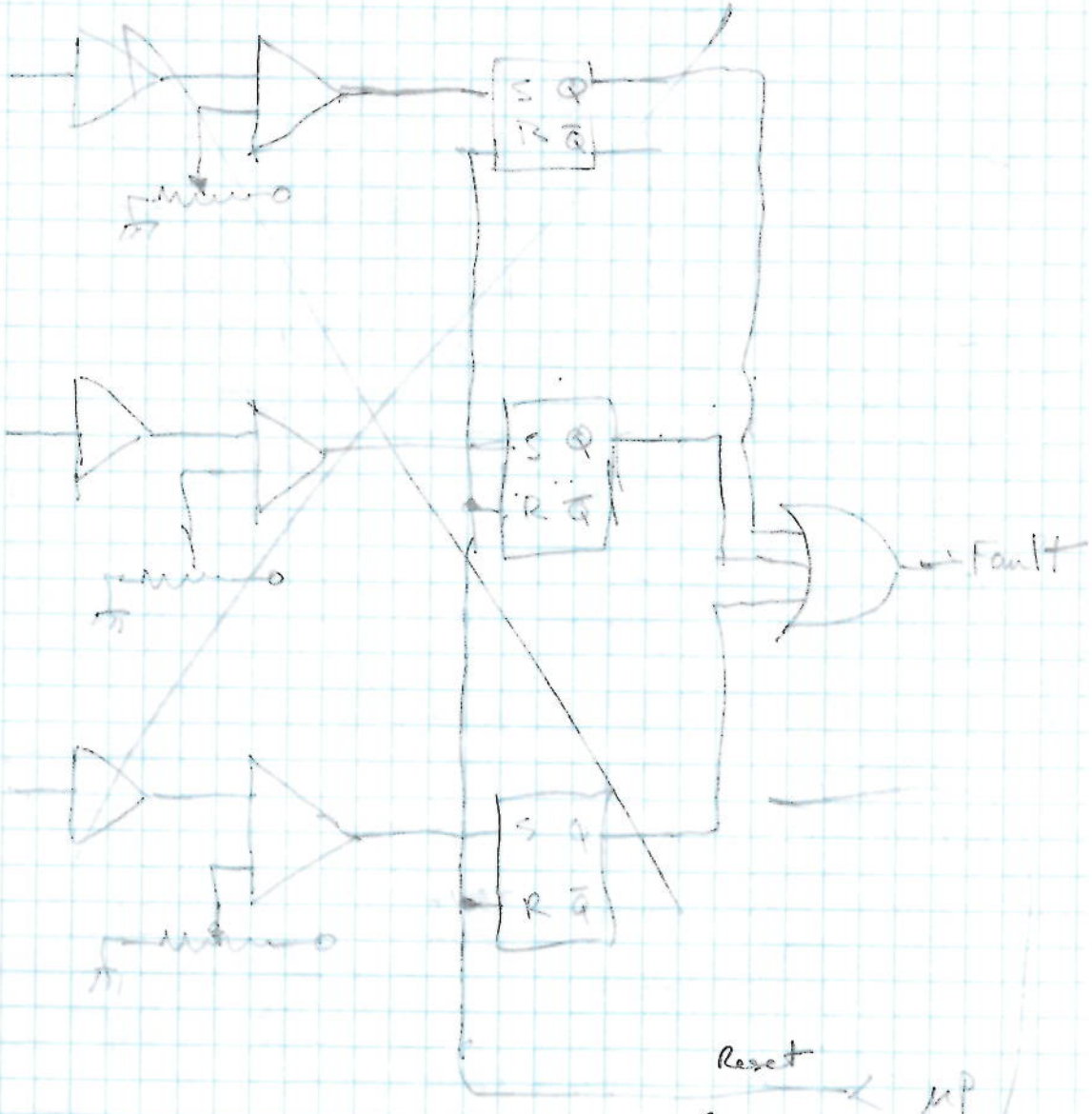


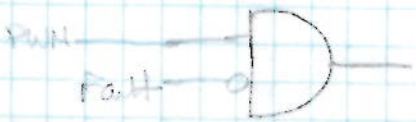
Adjust to equalize Neg + Pos Limit near 2.5V with trip set point pot at minimum

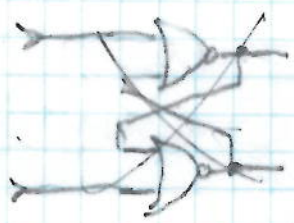


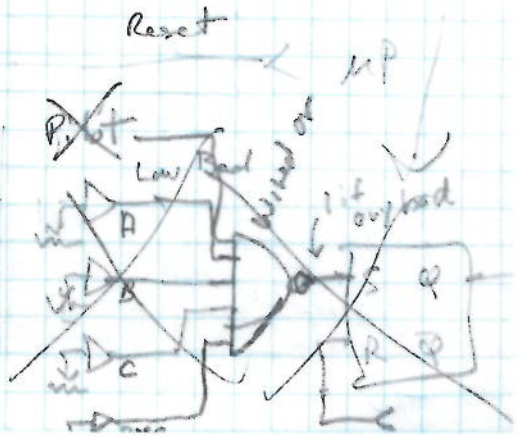


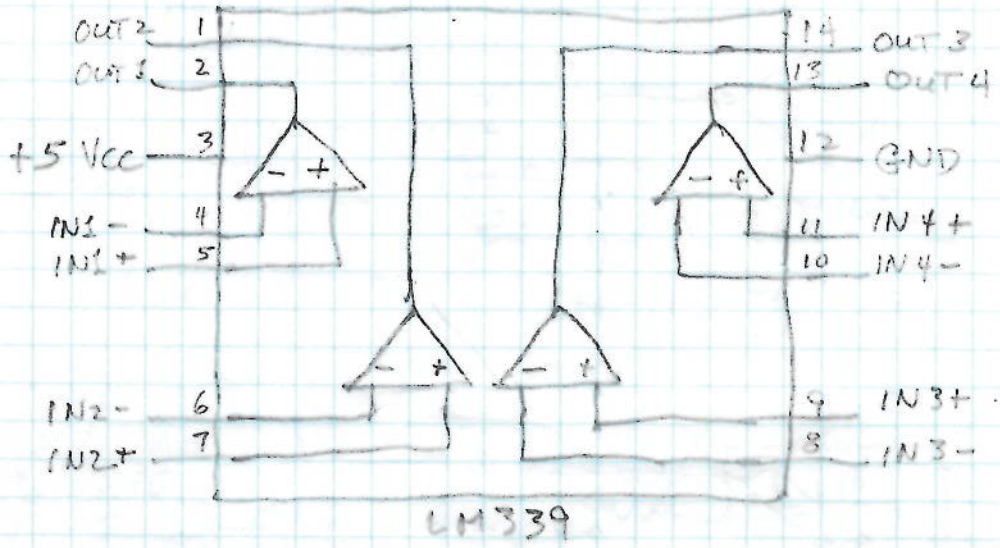
Over Current Protection



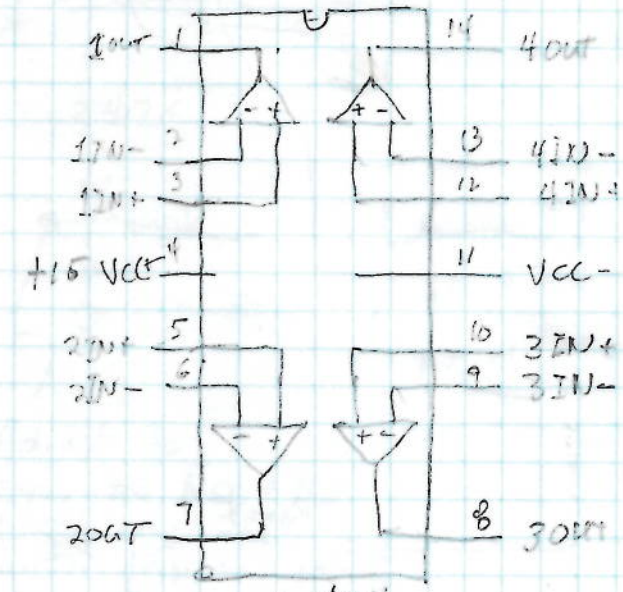








LM339



TL084

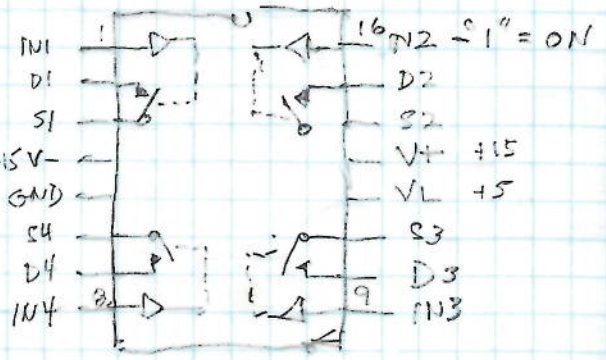
Sallen-key configs

2nd order Bessel

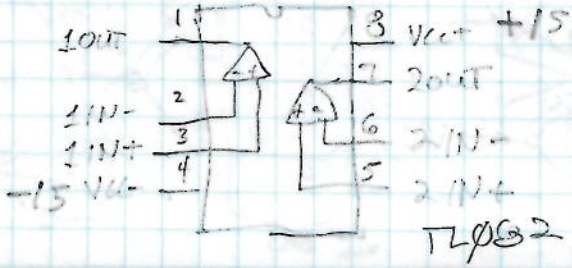
$a_i = 1.3617$ $b_i = 0.6180$

Butterworth

$a_i = 1.4142$ $b_i = 1.0000$



DG445



TL082

Parts Need

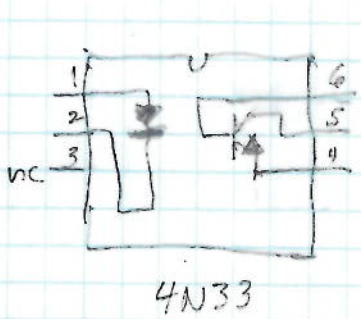
LM339 Comparator

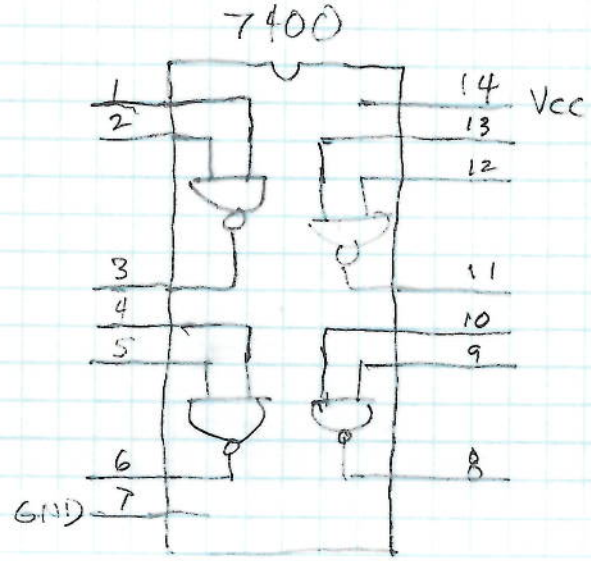
4.7uF @ 35V decoupling caps

22uF @ 35V " "

7 pin latching connector, not like LEM

DG445 DJ-E3 Quad SPST switch 16 DIP





J1-23 -> Solenoid (+)

J1-25 -> Precharge

J1-77,79 -> Coldplate thermistor
(GND)

R1 = 270

R2 = 390 = 3.04 ✓

R2 = 440 = 3.27

C2		J1	Signal	Cable
m	→	83	CCD+	white
S	→	84	CCD-	blue
r	→	73	Accel Sens 1	orange
CL, P, EE	→	33, 34	Sensor Gnd	Black/shield
g	→	.	+5V	Red
g	→	27	+5V	R/white str. PE
A	→	21	0.1 −	Yellow (Green on Cable)
B	→	22	0.1 +	Blue/white (yellow on Purple)

[redacted]

9/10 Doug to Hospital
Wed

8/31 - 9/1

(1) Found R-C filter added at LPC AI was C-R, not R-C. Took data anyway -

2538 typ value

file: with RC Backwards 3-1 volts.ods
"hash" ≈ 10 counts p-p w/ 9 excursions (negative) down to 2000 to 800 counts in 720 samples

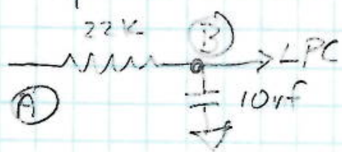
RC filter 3.8 × 10

(2) corrected filter to R-C 22K - 10,000 pF
took data

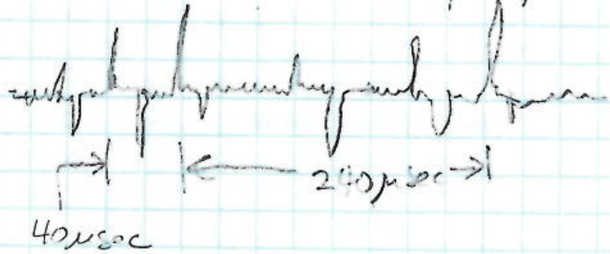
file; Proper RC 3-1 volts.ods

hash mostly 3 counts p-p (2578 ± 1) w/ some excursions ± 20 counts

'Scope shows at (A) < 4 mV p-p hash (20MHz bandwidth) with short bursts of negative 4mV additional "noise" - 2.8 msec long, 1 msec long, etc. Maybe about 100 msec period of spikes in bursts. Hash shows ~ 12 msec rep. spikes



at (3) 15 mV p-p hash with very repetitive pattern



(3) Removed Capacitor
Took data - file; R only 3-1 volts.ods
Appearance similar to (1) 'scope (B) shows distinct negative spike solid @ 200 µsec period.

'scope (A) similar to (2). Removed CAN bus chip - noise bursts

6 amps

± 1.5A.

(4) per (3) noise bursts apparently from CAN Bus. Added low inductance 3.3uF cap to CAN controller power bypass and to LPC for good measure. Scope shows no more bursts but still isolated spikes, always negative, apparently 4mV but maybe much longer?

Scope at (4)

When "get snap" active, much noise shows on scope -

file: R only CAN Bypass 3-1 volts.ads

same as (3) (5us/div 200kHz)

(5) Scope CH3-6,7 50mV

(6) Separated copper Ground Bus from board ground in attempt to institute separate digital & analog grounds. It looks like most or maybe all analog circuits are grounded to Copper bus. No change in data.

file: R only Analog Ground 3-1 volts.ads

(7) Removed 3.3V power - much nicer noise spectrum ~ 1mV p-p hash w/ <4mV p-p transients

(8) wired LPC ground to same point as new analog ground wire

Data file:

noise seems rather better - maybe strict separation of grounds is way to go.

(9) Connected LEM - wired in heater

at NKP AI
- zero current - no obvious additional noise
- heater on - 118 mV p-p sine wave centered at 1.72 volts

after correcting data collection file:
Heater with revised data collection code

(10) on above pot (20 watts of light bulb

~8 mV p-p with noise

noise ~ 4 mV p-p bursts
w/ bursts @ ~4.8 usec
base noise ~ 1 mV p-p

Noise same w/o lamps on
Noise same w/o LEM plugged in
Noise same w/ LEM inputs shorted

(11) LEM - no current. (also no 'scope probe)
file: zero current LEM.vds

(12) Added 33uF ± 0.1uF bypass caps to ±5 and ±15 V supply to board
file: zero current after bypass.vds

Resolver Emulator

Ref input sine wave $K_r \sin(\omega t)$

sin output $= K \cdot K_r \sin\theta \sin(\omega t)$

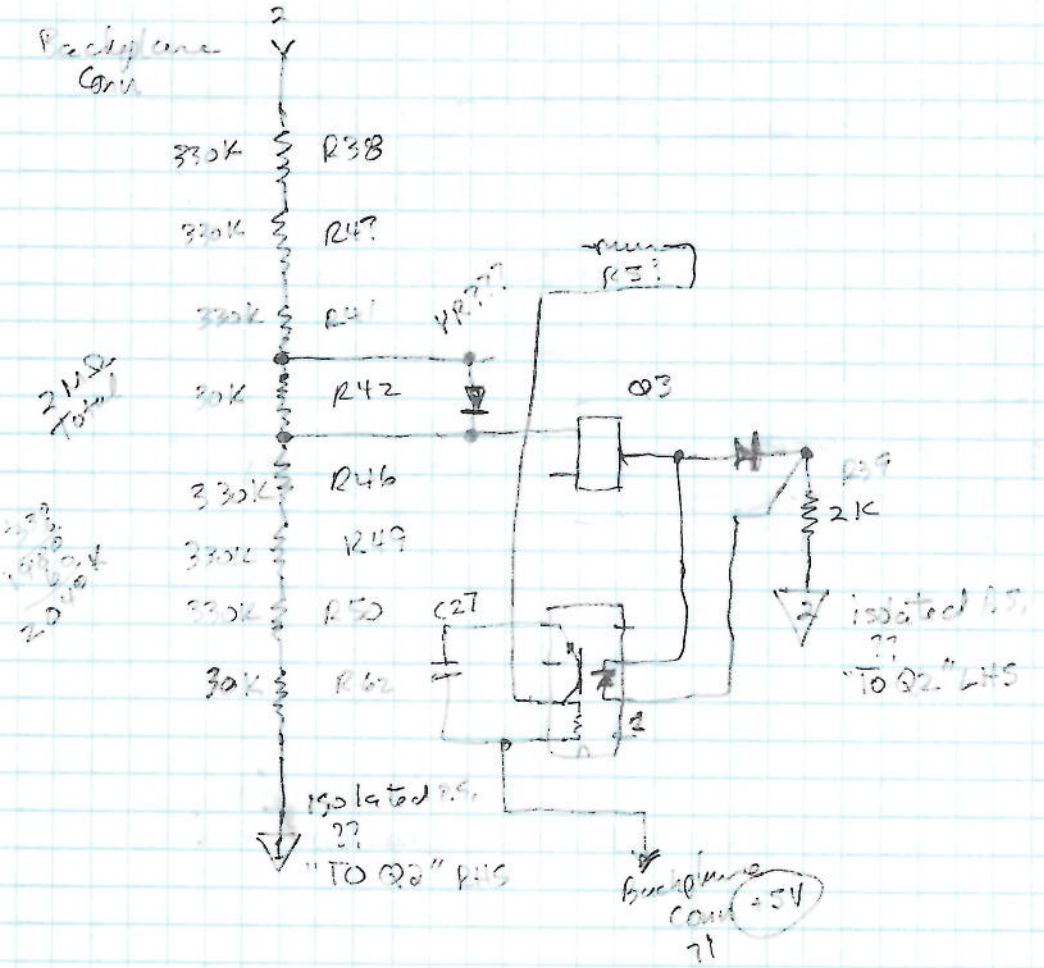
cos output $= K \cdot K_r \cos\theta \sin(\omega t)$

where θ is shaft position $\omega = 2\pi f$ = ref. frequency

if shaft is rotating at x rpm $= \frac{x}{60}$ rps

or $\omega_x = 2\pi \frac{x}{60}$

HV Circuit on Driver Board



MCP 3208 Cmd's

cmd4 is working but probably wrong

cmd4 was intended to be chan 0 single ended

when chan 1 is connected to bus current the zero current state reads 809 counts 2V - 1.66 = .44V. Disconn chan 0 Gives 3336, Disconn chan 1 Gives 1930 (old val)

using cmd 5 reads 0

cmd 8 - should be single ended chan 0, is dif 1,0

cmd 4 should be diff chan 4,5, is dif 0, 1

5.2ip 9.2ip

0 - 0 0000|0000 dif 0,1 0
0000 1000 dif 1,0 1
0001
0100 0...
4 0

0 - 4092 pegged
1 - 3225, slightly reacts to both 0, 1
4 - 0 1 b
5 - ?
8 - 10 b
9 - ?
x 40 - like 0
x 48 - ?

5 5
0101 0101
A A
1010 1010

x40 - Dif
x80 - bit rev
x20 - ?
x10 - ?
x08
x04

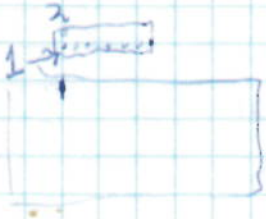
1|1000

start bit needs to be 1 bit

J1 - C2 Connections

Group

C2	J1		C2	J1
✓ g	27	5V	E, C, G, H, DD, CC, S, EE, BB, P, J, K, L, M, N,	1-20
✓ P	17	GND		
✓ r	73	Accel		
✓ m	83	Can +	g, AA, g, A, B, +,	21-40
✓ S	84	Can -	CC, c, BB, p, X, Z, f, R, N,	41-60
✓ g	28	5V		
AA	24	pump pressure (+)	N, R, K, S, X, Y, Z, m, FF, d, c, E, BB, HH, EE, CC, y, V, L, W	61-80
BB	18	pump Press (-)		
B	22	oil pump -		
A	21	oil pump + 42	N, R, b, f, [illegible], Z, Y, S, E, BB, EE, S, CC, S	81-100
	34	fan - (GND), 19		
	63	fan +		



(test)

J7-1 Phase A filter out
J7-2 +5V
J7-5 Phase A A-D in
J7-6 ~15V
J7-7 Phase C filter out
J7-9 FAN
J7-11 Ored Fault
J7-13 Latched Fault

Smooth ORPM tuning 11/13/14

try	Result
P(Q+D) from .8 to .2	Less energy, B = 5Hz 15ft-lbs
Poles from 4 -> 2	Faster more energetic, B=5Hz
Poles 2->4 Magtable@ORPM 500 -> 100	3$ft-lbs B = 20Hz
Magtable@0 500 -> 750	15$ft-lbs, B = 2-3Hz
Magtab@0 750-1000	15$ft-lbs, B = .5-1 broke string...
Magtab@0 1000->1250 Filter 2->25	18$ft-lbs B=0-.5 very strong but also sudden torque...
remove pos. rpm sense (tst)	B = 1
reduce Tr 0.04 -> .02..	B = 5
reduce Tr .02.. -> .01..	"
Poles 4->2 Tr .01->.005	No torque all Amps
Tr .005->.3	high Freq B 30+? Low torque
Tr .3 -> .03183, mod slip Alpha Also replaced R6 10k->1k	--> maxed scale some pulse good speed
Adjust Current limit to .75 -> 1.5V	Limit is ok but transient spikes affect CANBUS!

Te measurement – Bob's motor

Run 1 $\ln \Delta V = 2.93$

$\Delta t = 0.04$

$TR = 117$ msec

Run 2 $\Delta V = 15$ V

$Tr = 108$

Run 3 $Tr = 108$

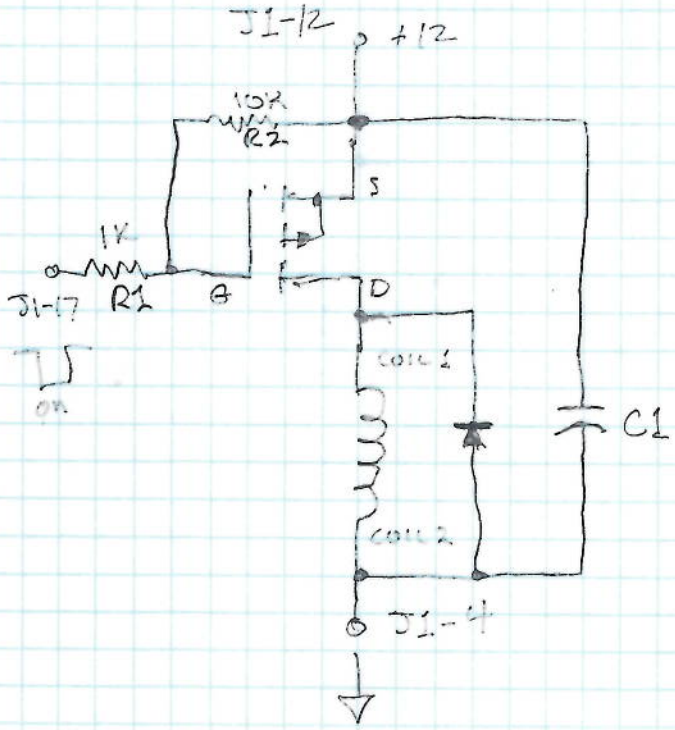
→ AMP EVC500-ALAAAA

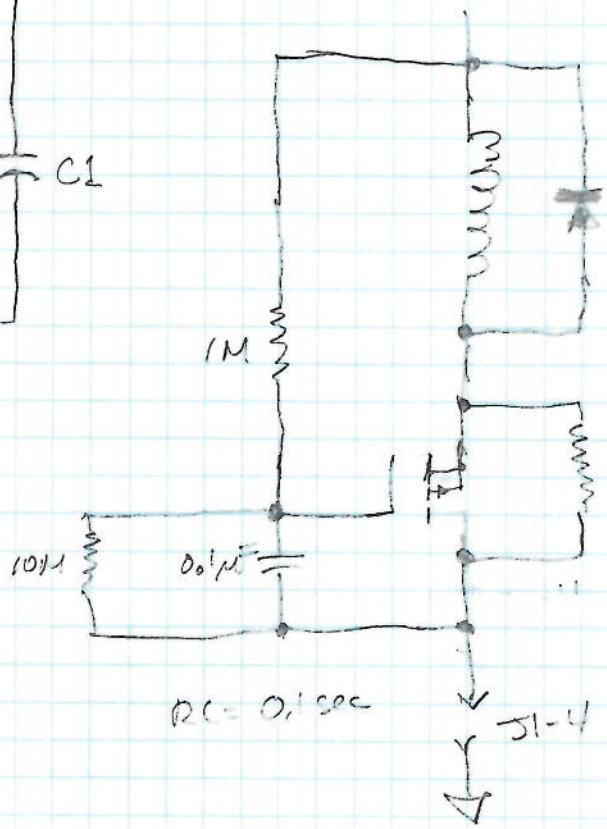
aka

↳ Tyco Electronics

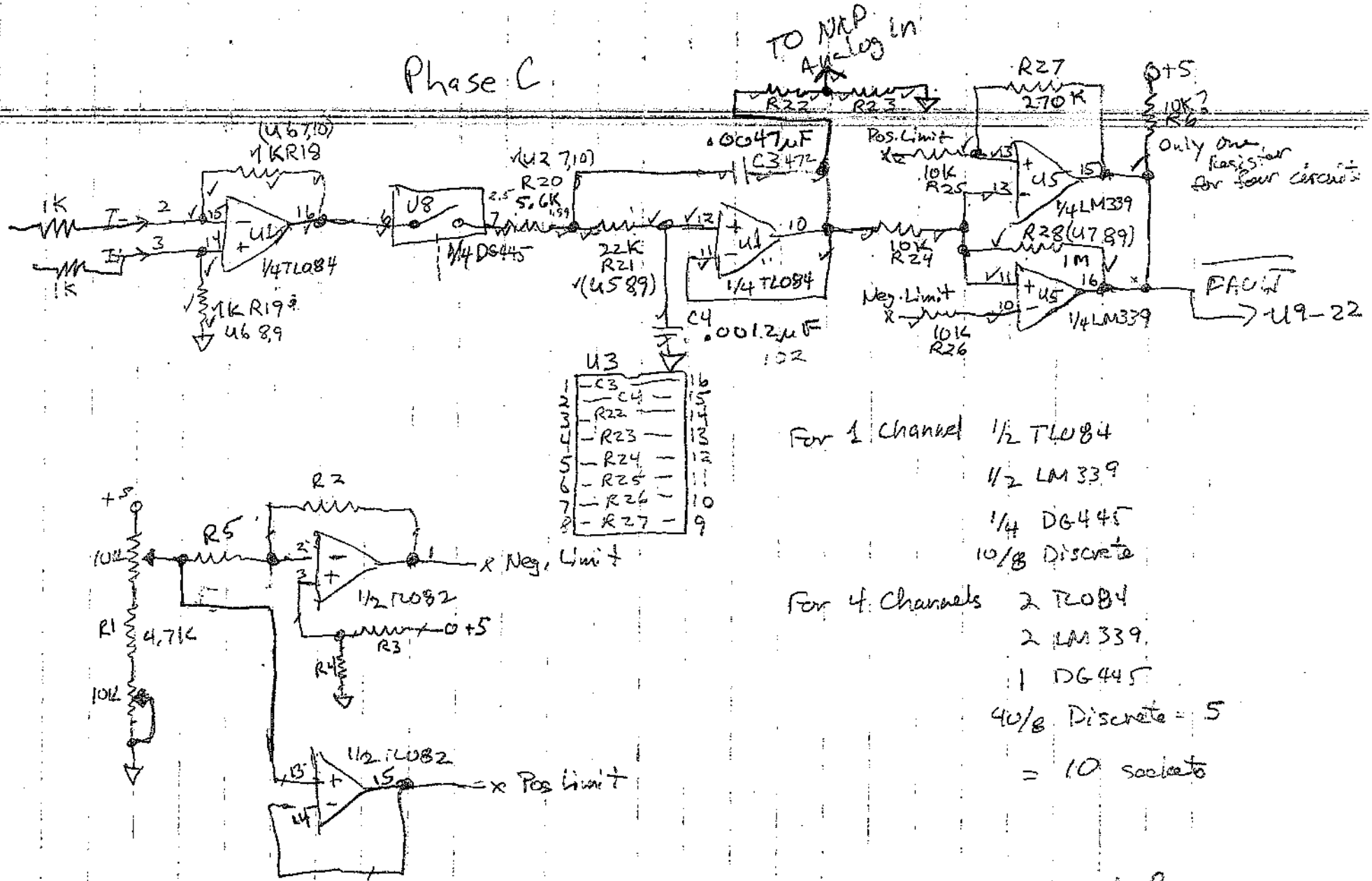
2098372-1

12-24 VDC coil





Phase C



For 1 Channel
- 1/2 TL084
- 1/2 LM339
- 1/4 DG445
- 10/8 Discrete

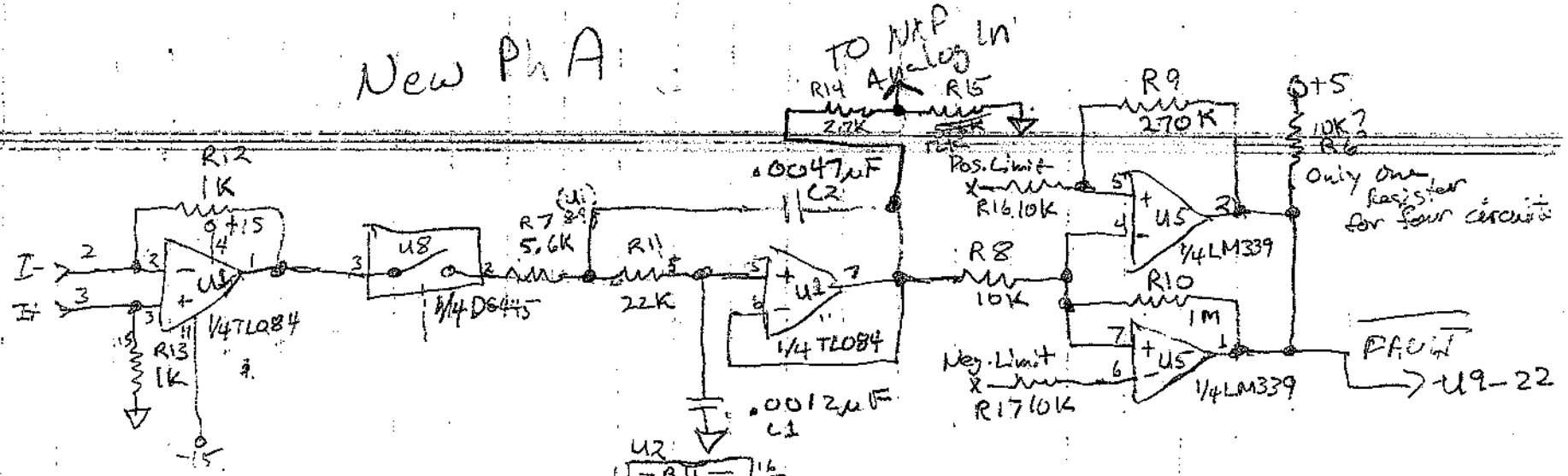
For 4 Channels
- 2 TL084
- 2 LM339
- 1 DG445
- 40/8 Discrete = 5
- = 10 sockets

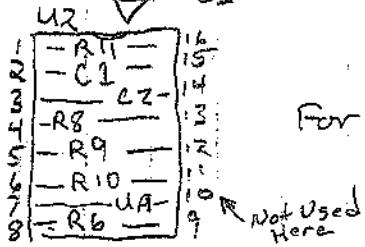
4/8 discrete = 0.5 sockets
1 TL082 = 0.5 sockets
} 1 socket

9 + 11 sockets

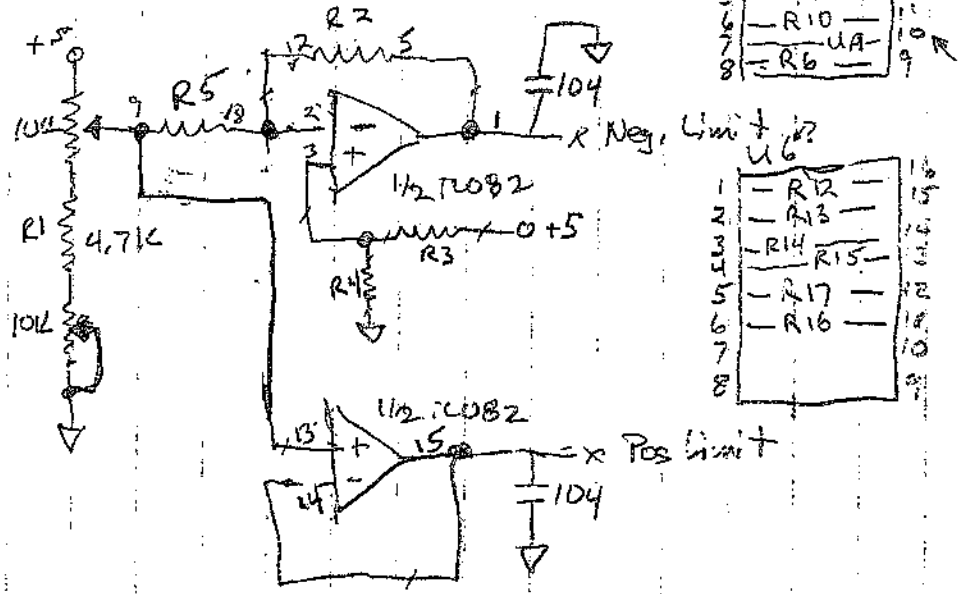
Grand Total

New PhA





For 1 Channel 1/2 TL084
1/2 LM339
1/4 DG445
10/8 Discrete

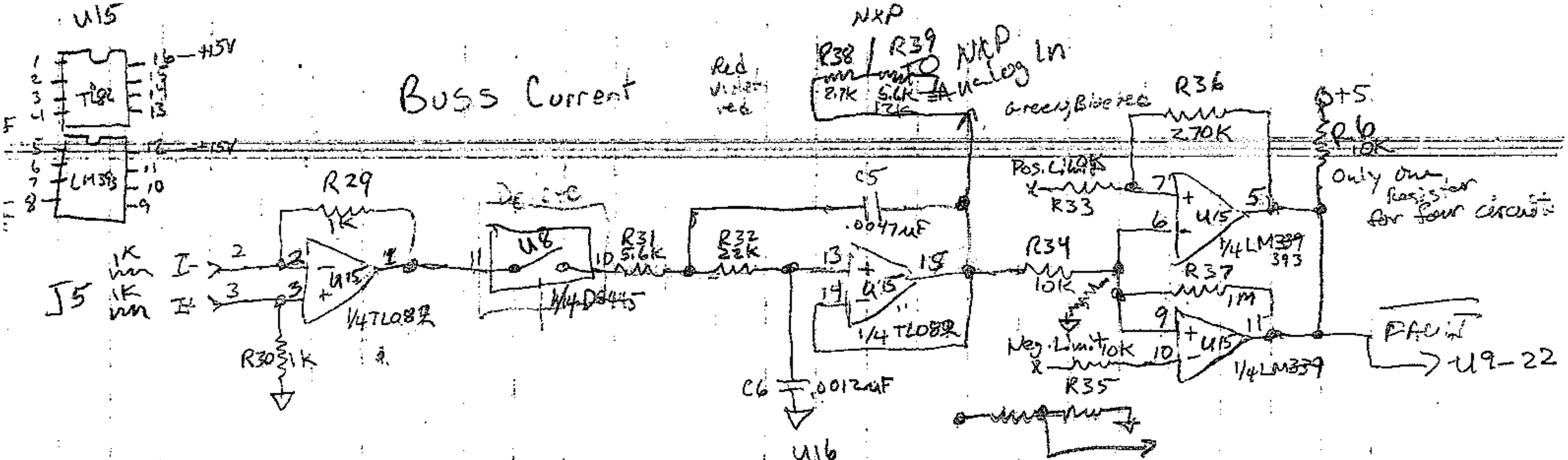


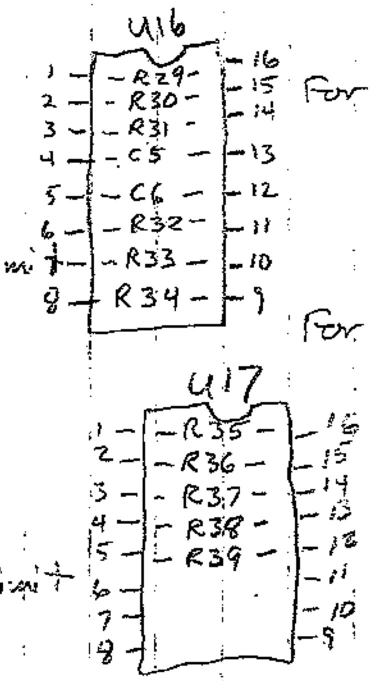
For 4 Channels 2 TL084
2 LM339
1 DG445
40/8 Discrete = 5
= 10 sockets

4/discrete = 0.5 sockets
1 TL082 = 0.5 sockets
} 1 socket

Grand Total
9 + 11 sockets

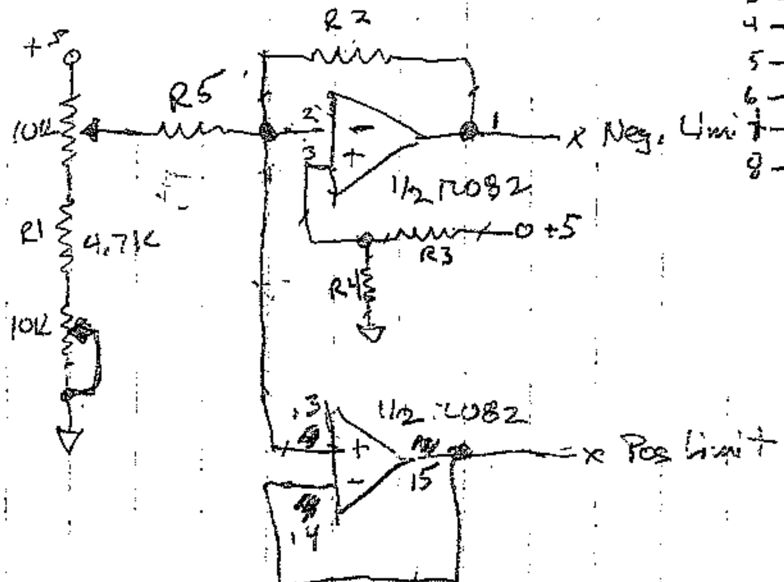
Buss Current





For 1 Channel 1/2 TL084
1/2 LM339
1/4 DG445
10/8 Discrete

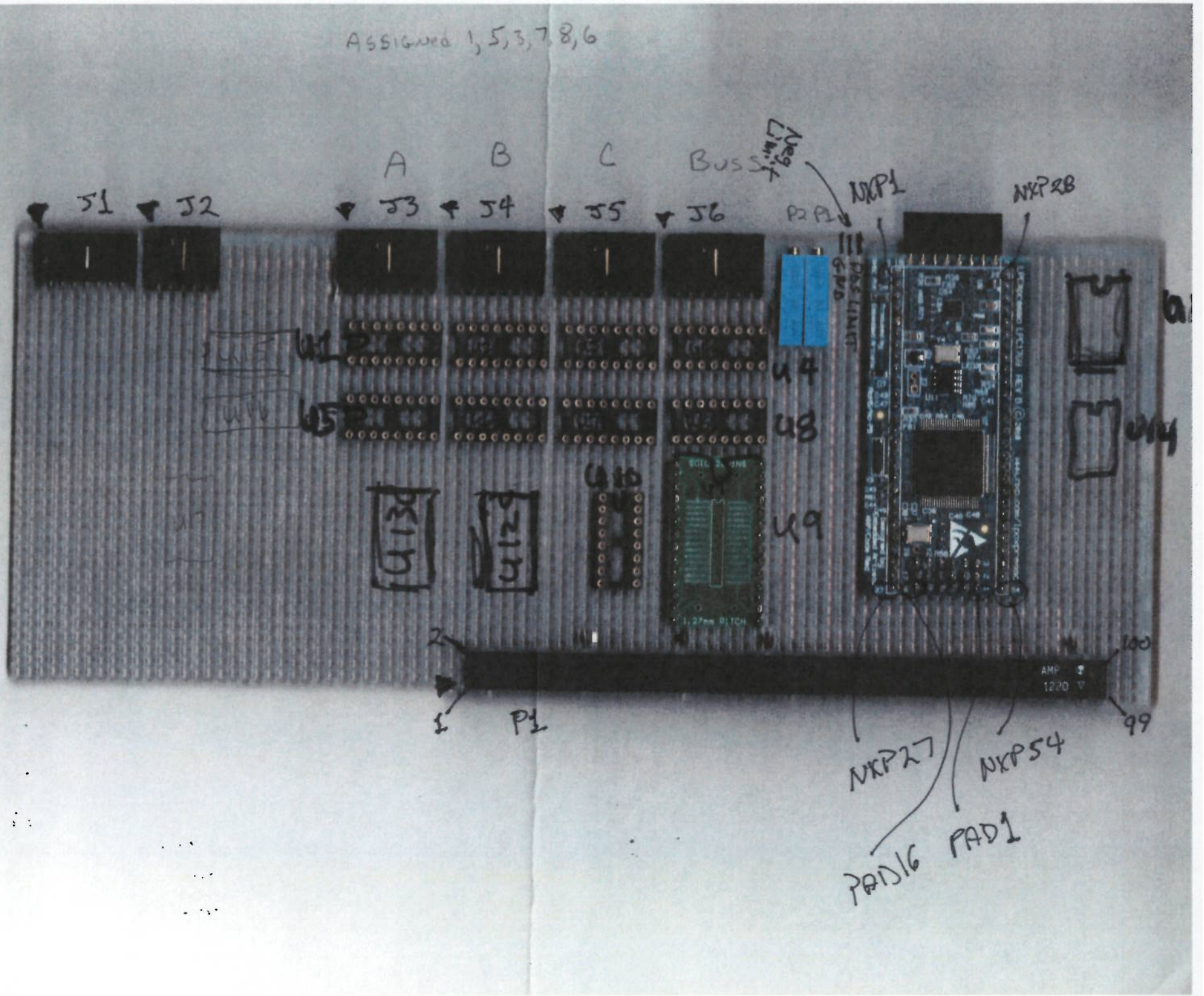
For 4 Channels 2 TL084
2 LM339
1 DG445
40/8 Discrete = 5
= 10 sockets

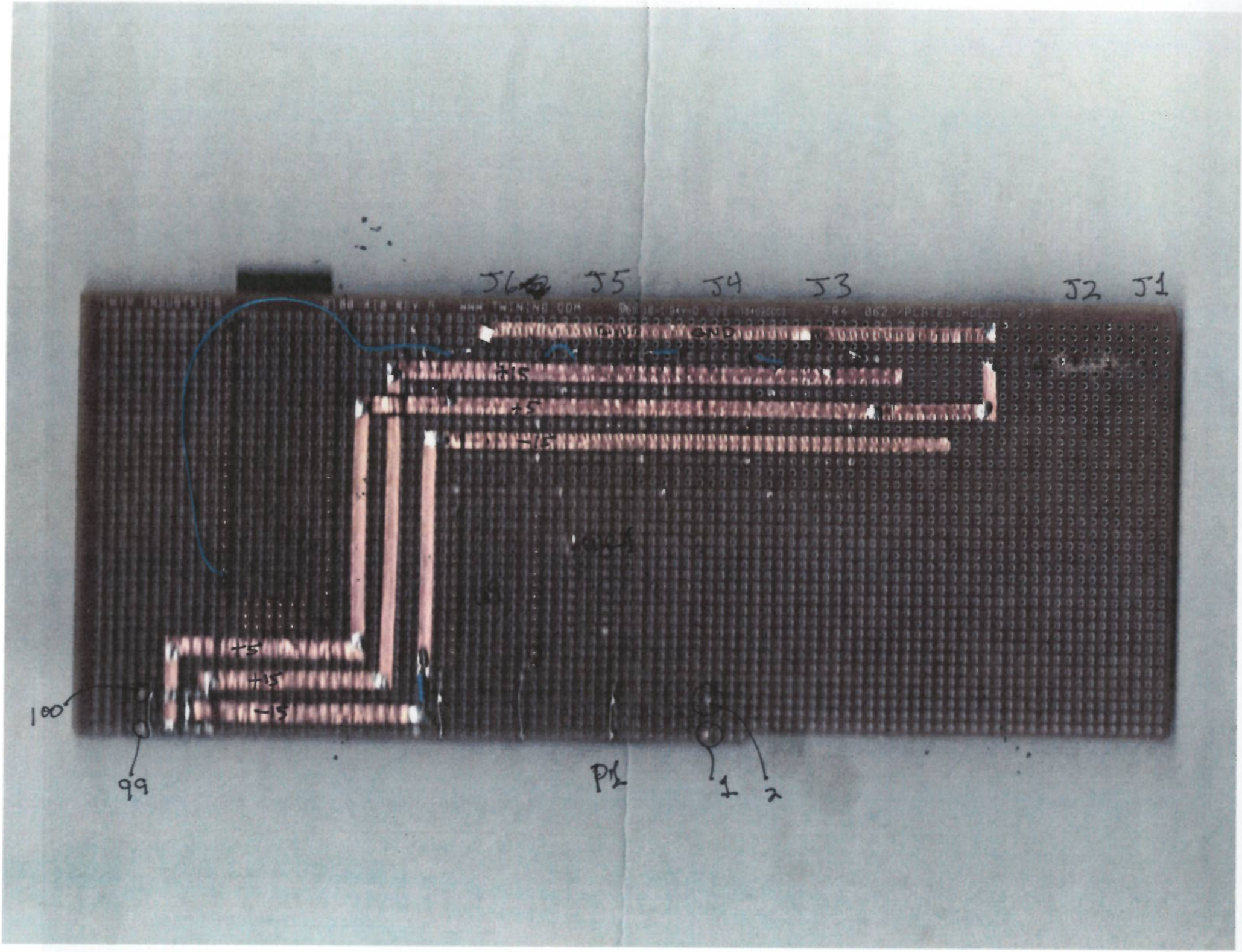


Grand Total

4/8 discrete = 0.5 Sockets
1.1 TL082 = 0.5 sockets
} 1 socket

+ 11 sockets


ASSIGNED 1, 5, 3, 7, 8, 6
A
B
C
BUSS
J1
J2
J3
J4
J5
J6
P2
P1
NXP1
NXP2B
U1
U5
U4
U8
U9
U10
U12
U13
U14
1
2
99
100
P1
NXP27
NXP54
PAD16
PAD1


J6
J5
J4
J3
J2
J1
GND
+5
+5
-5
+5
+5
-5
100
99
P1
1
2

Decouple U9, 10, 12, 13

NxP Power

GND -> J6-1, J6-5 ✓ decouple
+5 ✓ -> J6-2

CAN

U11-15 (CanH) ✓ -> ✓ J1-83
U11-14 (CanL) ✓ -> ✓ J1-84

U11-2 ✓ decouple
U11-3 ✓

Current limit reference

U4-4 ✓ -> ✓ -15V
U4-16 ✓ -> ✓ +15V
U4-1 ✓ -> ✓ U4-5 -> Neg limit
U4-12 ✓ -> ✓ U4-2
U4-3 ✓ -> ✓ U4-6
U4-11 ✓ -> ✓ +5V
U4-6 ✓ -> ✓ U4-7
U4-10 ✓ -> ✓ GND
U4-2 ✓ -> ✓ U4-13
U4-15 ✓ -> ✓ U4-14 -> Pos limit
U-4-2 ✓ -> ✓ R13
U4-9 R5 ✓ -> ✓ Pot1 (center)
Pot1 (top) ✓ -> ✓ +5V
Pot1 (bot) ✓ -> 21
R1 ✓ -> Pot2 (top)
~~Need 1 more Res location~~
Pot2 (center) ✓ -> ✓ Pot2 (bot)
Pot2 (bot) ✓ -> ✓ GND
U4-8 ✓ -> ✓ U4-2

Phase A current J3

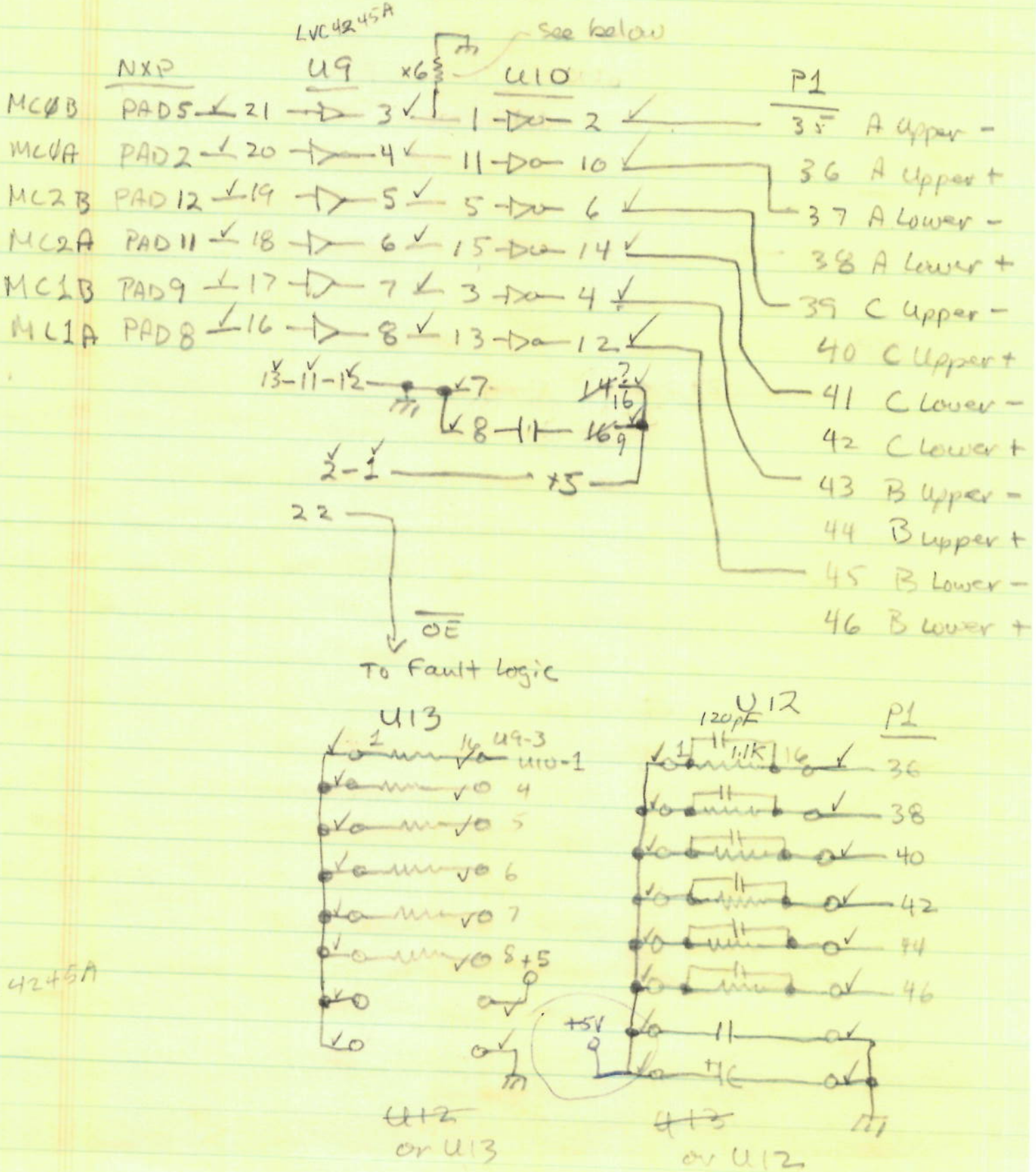
TL084
U1

J3-2 ✓→✓ U1-2 ~~U1-2 → U3-1~~ U1-4 ✓→✓ +15V
J3-3 ✓→✓ U1-3 ~~U3-16 → U1-2~~ U1-13 ✓→✓ -15V
U1-1 ✓→✓ U8-3 ~~U1-3 → U3-2~~ U8-4 ✓→✓ -15V
U8-2 ✓→✓ U1-8 ~~U3-15 → GND~~ U8-5 ✓→✓ GND
R7-9 5.6K U1-9 ✓→✓ U2-1 ~~U6-3 → U2-14~~ U8-12 ✓→✓ +5V
U2-16 ✓→✓ U1-5 ~~U6-14 → U6-13~~ U8-13 ✓→✓ +15V
LM1458
U8
U1-6 ✓→✓ U1-7 ~~U6-4 → GND~~ U5-3 ✓→✓ +5V
U1-9 ~~(U2-1)~~ ✓→✓ U2-3 ~~U6-14 → J6-22~~ U5-14 ✓→✓ GND
U1-16 ✓→✓ U2-2
U2-15 ✓→✓ GND
U1-7 ✓→✓ U2-4 U6-5 ✓→✓ U5-6 J3-5 ✓→✓ +15V
LM339
U5
U2-13 ✓→✓ U5-4 U6-12 ✓→✓ U4-1 U6-4 ✓→✓ J6-22 AI6
U2-13 ✓→✓ U5-7 U2-9 ✓→✓ +5V
U5-5 ✓→✓ U2-5 U6-6 ✓→✓ U5-5
U5-2 ✓→✓ U2-12 U6-11 ✓→✓ U4-15
U5-7 ✓→✓ U2-6
U2-11 ✓→✓ U5-1
U5-1 ✓→✓ U5-2
U5-2 (U2-12) ✓→✓ U2-8
U2-9 ✓→✓ +5V
U6-1 ✓→✓ U1-2
U6-16 ✓→✓ U1-1
U6-2 ✓→✓ U1-3
U6-15 ✓→✓ GND

Head unit Cable
Red +12V
Grn GND
Blue CANL
Yellow CANH

U6-14 ✓→✓ U2-14
U6-3 ✓→✓ U6-4
U6-13 ✓→✓ GND
U6-3 → MAX J6
U2-14 ✓→✓ U2-7

IGBT DRIVE


LVC4245A
see below
NXP
U9
x6
U10
P1
MC0B PAD5 21 3 1 2 3 5 A Upper -
MC0A PAD2 20 4 11 10 36 A Upper +
MC2B PAD12 19 5 5 6 37 A Lower -
MC2A PAD11 18 6 15 14 38 A Lower +
MC1B PAD9 17 7 3 4 39 C Upper -
MC1A PAD8 16 8 13 12 40 C Upper +
41 C Lower -
42 C Lower +
43 B Upper -
44 B Upper +
45 B Lower -
46 B Lower +
13-11-12
7
8 11 16
9
2-1
+5
22
OE
To Fault logic
U13
1
16
U9-3
U10-1
4
5
6
7
8
+5
U12
120pF
1.1K
1
16
36
38
40
42
44
46
+5V
9
U12
or U13
U13
or U12

Buss Current

- ✓ J5-2 → U15-2
- ✓ J5-3 → U15-3
- ✓ U15-3 → U16-2
- ✓ U15-2 → U16-1
- ✓ U16-16 → U15-1
- ✓ U16-15 → GND
- ✓ U15-1 → U16-3
- ✓ U16-14 → U16-6
- ✓ U16-14 → U16-4
- ✓ U16-11 → U16-5
- ✓ U16-12 → GND
- ✓ U16-12 → U15-13 (should be U16-11)
- ✓ U15-14 → U15-15
- ✓ U15-14 → U16-13
- ✓ U16-13 → U17-4
- ✓ U17-13 → U17-12
- ✓ U17-5 → GND
- ✓ U17-12 → NXP(J6-17)
- ✓ U15-15 (U17-4) → U16-8
- ✓ U16-9 → U15-6, 9
- ✓ U4-1 → U17 1
- ✓ U4-15 → U16-7
- ✓ U16-10 → U15-7
- ✓ U17-16 → U15-10
- ✓ U15-7 → U17-2
- ✓ U17-15 → U15-5
- ✓ U15-9 → U17-3
- ✓ U17-14 → U15-11
- ✓ U15-5 (U17-15) → U15-11 (U17-14)
- ✓ U15-5 all → U2-8 (U5-15)
- ✓ U15-16 → +15V
- ✓ U15-8 → GND
- ✓ J5 4, 6 → GND
- ✓ J5-5 → +15V
- ✓ U15-4 → -15V
- ✓ U15-12 → +5V

J6

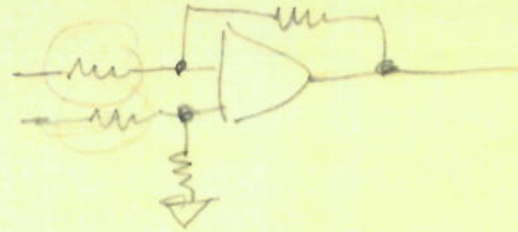
Phase C current

J4-2 ✓→✓ U1-15
J4-3 ✓→✓ U1-14
U1-16 ✓→✓ U8-6
U1-15 ✓→✓ U6-7
U1-16 ✓→✓ U6-10
U8-7 ✓→✓ U2-7
U2-10 ✓→✓ U5-8
U6-8 ✓→✓ U1-14
U6-9 ✓→✓ GND
U5-9 ✓→✓ U1-12 —
U1-10 ✓→✓ U1-11
U2-10 ✓→✓ U3-1
U3-16 ✓→✓ U1-10
U1-10 ✓→✓ U3-3
U3-14 ✓→✓ U3-13
U3-4 ✓→✓ GND
U3-13 ✓→✓ Nxp (J6-21) AI7
U3-2 ✓→✓ U5-9
U3-15 ✓→✓ GND
should be U4-15 ✱ U4-1 ✓→✓ U3-6 —
U3-11 ✓→✓ U5-13
should be U4-1 ✱ U4-15 ✓→✓ U3-7
U3-10 ✓→✓ U5-10
U1-10 ✓→✓ U3-5
U3-12 ✓→✓ U5-12→11
U5-11 ✓→✓ U7-8
U7-9 ✓→✓ U5-16

J4

U5-15 ✓→✓ U5-16
U3-8 ✓→✓ U5-13 (U3-11)
U3-9 ✓→✓ U5-15 (U2-8)
U5-15 ✓→✓ U2-8

J4-4 ✓→✓ GND
J4-5 ✓→✓ +15V
J4-6 ✓→✓ GND



Code

~~Clear msg's~~, ~~Jog up/down~~, ~~test snapshot~~, ~~New temp table~~

mk II

populate ϕA limit + decouple

~~track & resistor bridge temp sensor~~

~~mkIV left side board support~~

DegF	Counts
180	482
165	584
150	745
111	1385
82	2108
75	2191
38	2901
25	3079

Punch for Phase A limit

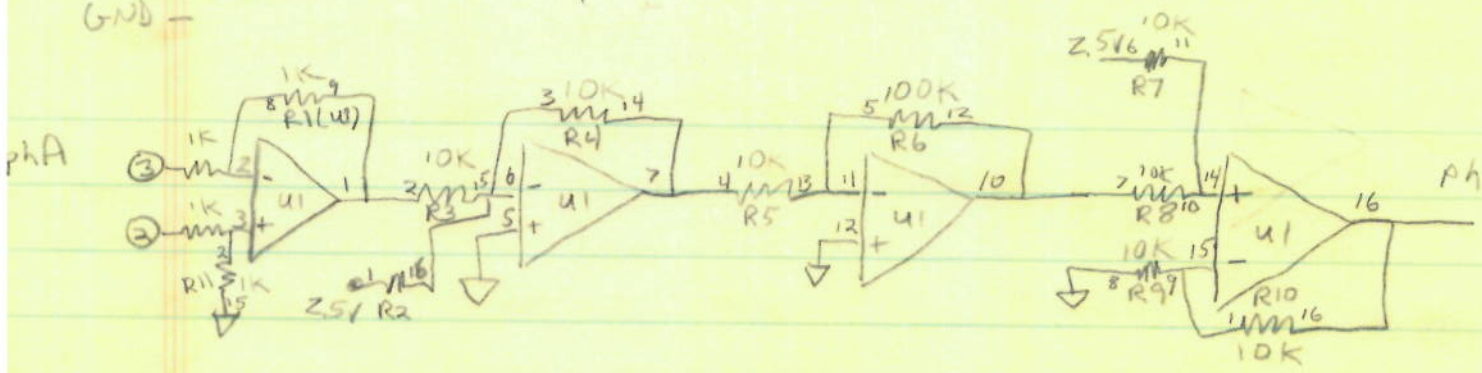
- √ ① U8 - 2&3 on wrong pins
- √ ② R6-R7 label & re-wire

To Do

- √ ~~① Decouple HC04 & level cut~~ (U10 U9)
- √ ~~② Solder lvl cut~~
- √ ~~③ SW imp of fault/reset~~
- √ ~~④ Latch circuit design & locate~~
- √ ~~⑤ SW I's to Head unit~~
- √ ~~⑥ Latch wire & test fault/reset~~
- √ ~~⑦ Head cable shell~~
- √ ~~⑧ Populate U12-U13~~
- √ ~~⑨ Switch polarity~~

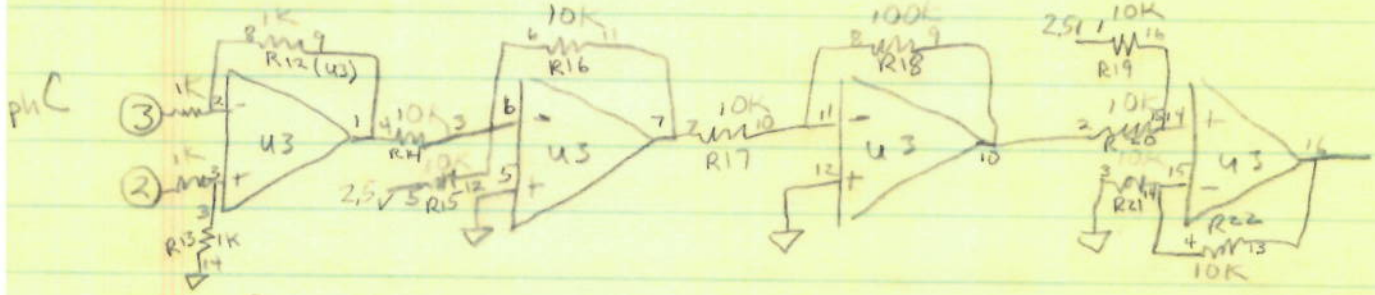
PRE-AMP

+15V —
−15V —
GND —

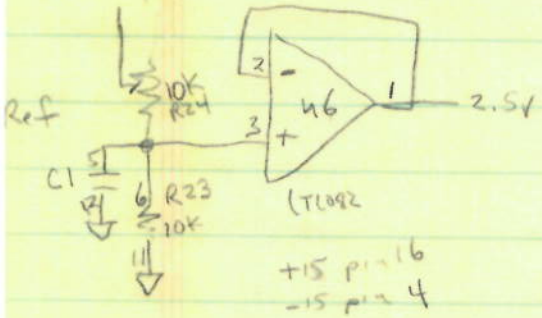


+15 pin 4
−15 pin 13

62500 - 64500

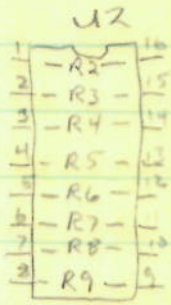


4.096 Ref



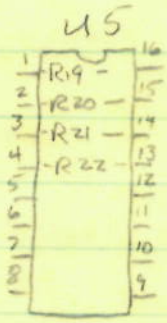
+15 pin 16
−15 pin 4

U2

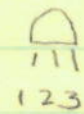


U4

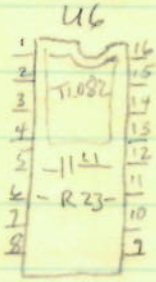
U5

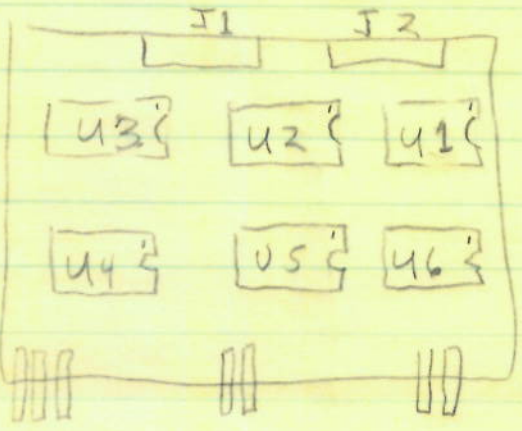


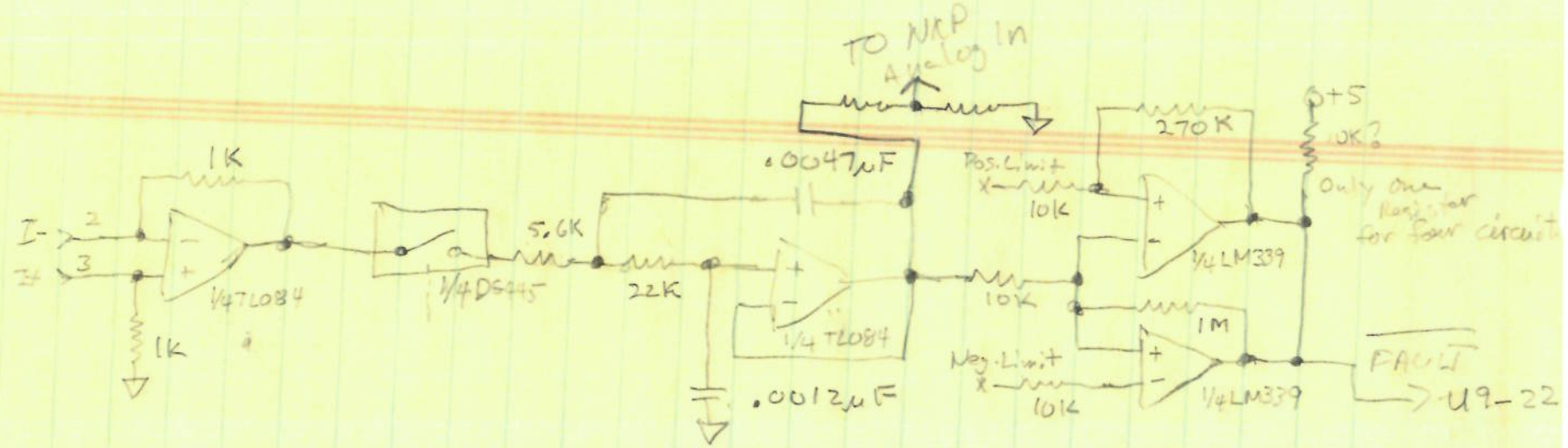
MCP1541

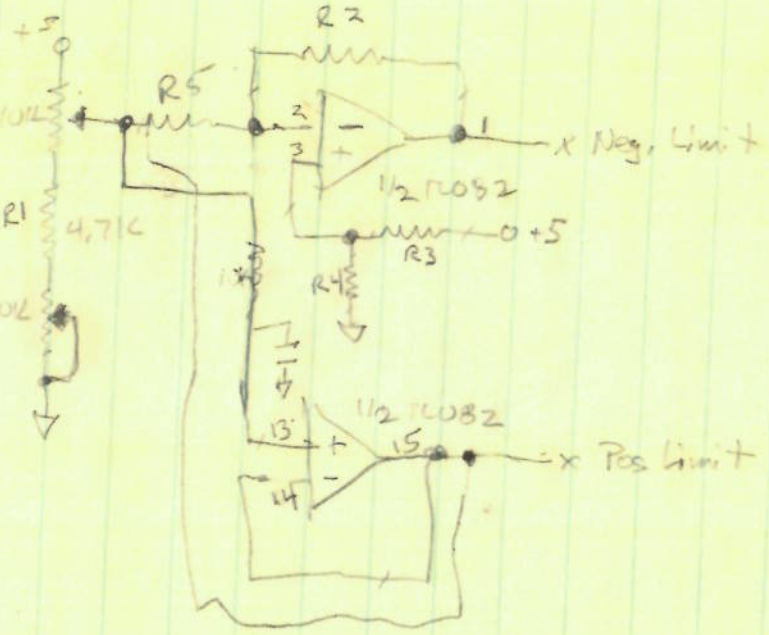


U6









For 1 channel
- 1/2 TL084
- 1/2 LM339
- 1/4 DG445
- 10/8 Discrete

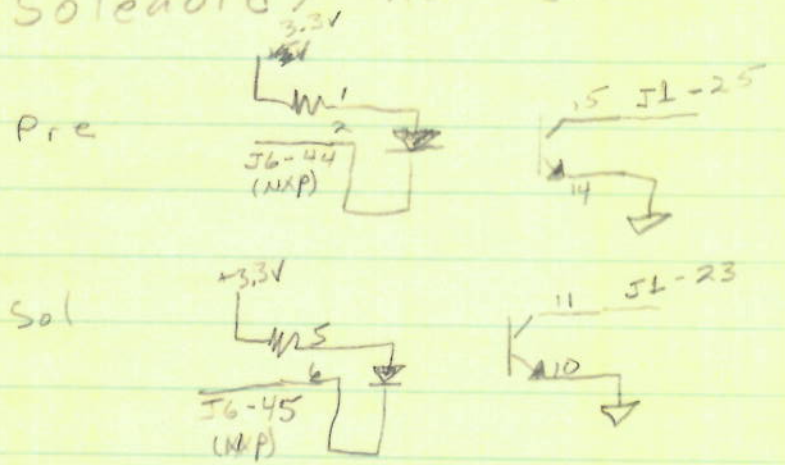
For 4 channels
- 2 TL084
- 2 LM339
- 1 DG445
- 40/8 Discrete = 5
- = 10 sockets

4/discrete = 0.5 sockets
1 TL082 = 0.5 sockets
} 1 socket

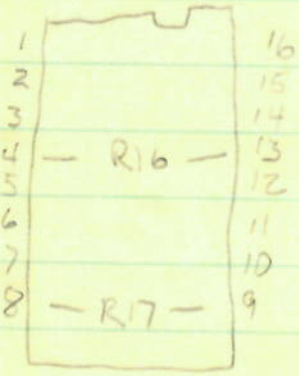
Grand Total
9 + 11 sockets

Pre charge / Solenoid / Thermistor

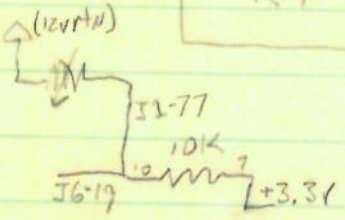
Pre
- U14-1 → U14-4
- U14-13 → +3.3V
- U14-2 → J6-44
- U14-14 → GND
- U14-15 → J1-25



Sol
- U14-5 → U14-8
- U14-9 → +3.3V
- U14-6 → J6-45
- U14-10 → GND
- U14-11 → J1-23



thermistor
- U11-7 → +3.3V
- U11-10 → J6-19
- J1-77 → U11-10



Resolver

Mark IV Backplane Connector = P1

To Resolver			P.C.O Board
Ref+	P1-1 ←	J1-1 ✓ ←	J3-1
Ref-	P1-2 ←	J1-2 ✓ ←	J3-2
Cos+	P1-3 →	J1-3 ✓ →	J1-4
Cos-	P1-4 →	J1-4 ✓ →	J1-5
Sin+	P1-5 →	J1-5 ✓ →	J1-1
Sin-	P1-6 →	J1-6 ✓ →	J1-2
Gnd	P1-8 ↔	J1-7 ✓ ↔	J1-3

	NXP J2		
PhA (MCI0)	PAD3 ← J2-1 ← P1-1	A+	✓
PhB (MCI1)	PAD6 ← J2-2 ← P1-3	B+	✓
IDX (MCI2)	PAD7 ← J2-3 ← P1-5	Z+	✓
	Bus Bar - J2-5 - P1-9	+5V	✓
	Gnd Plane - J2-4 - P1-10	GND	✓

CAN Bus