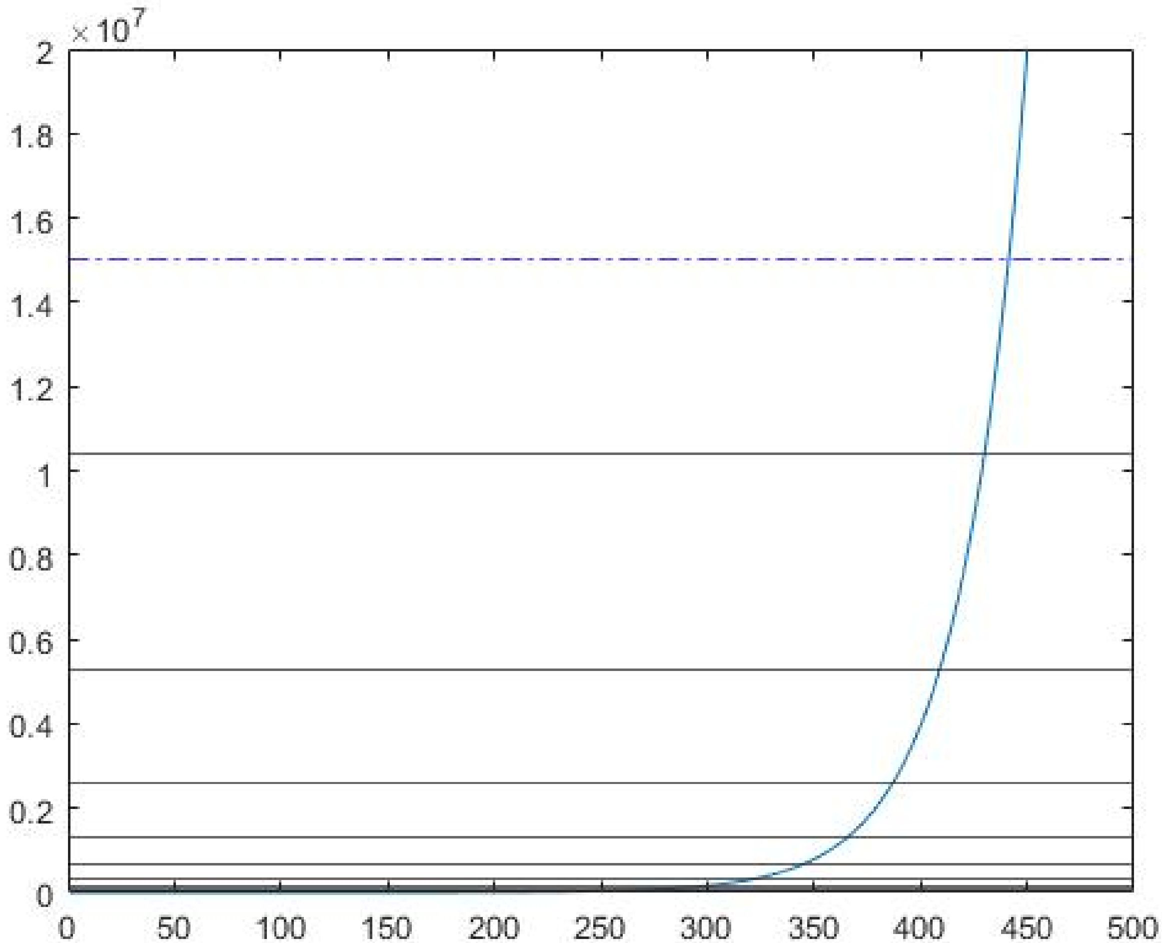
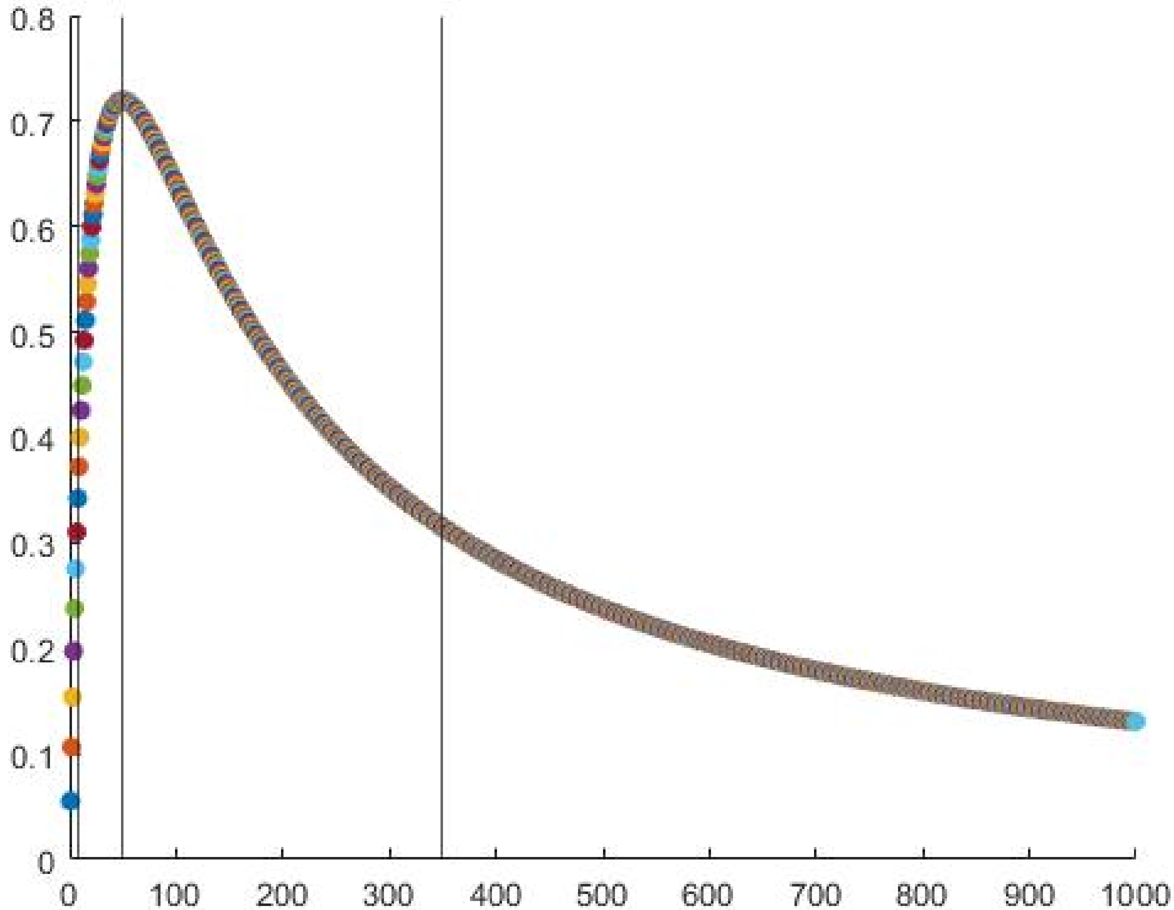
IMPEDANCE MATCH DOCUMENTATION



octave

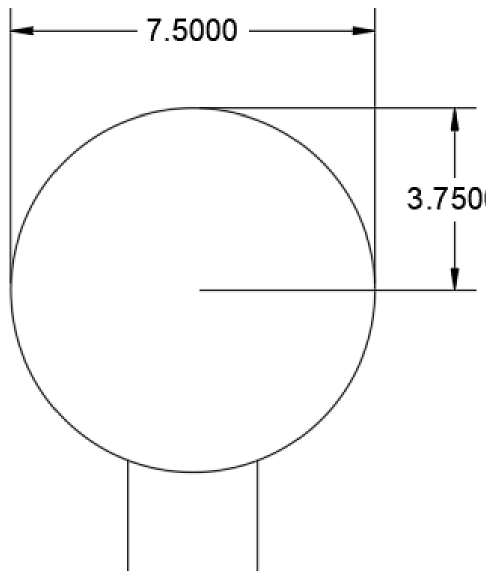
19.7055780	161590.8753896	328877.4285826
2	15	16
40.1057288	2587.1740786	648071.9826312
3	9	17
79.0306568	5098.1760644	1318986.8961987
4	10	18
160.8469483	10376.0501977	2599139.9183829
5	11	19
316.9582089	20446.6066658	5289893.0760982
6	12	20
645.0884089	41613.9055332	10424040.0702156
7	13	21
1271.1839969	82002.6061993	21215501.7136245
8	14	22

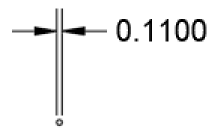
```
numfreq = 500;
y = logspace(1,8,numfreq);
stopFreq = y(numfreq);
startFreq = y(1);
a = double(startFreq);
c = 1;
figure(4);
plot(y);
xlim([0 numfreq]);
ylim([0 20000000]);
yline(15*10^6,'-.b');

while a <= 15000000

a = a*2;
[val,idx]=min(abs(y-a));
minVal=y(idx);


fprintf('%.7f\n',minVal)

yline(minVal);

c = c+1;
disp(c);

end
```




```
Vs = 12;
Zs = 50;
Zl = 0;
PL = 0;
figure(2);
scatter(Zl,PL,'filled');
x = [];
for c = 1:1000
Zl = Zl+1;
PL = (((Vs)/(Zs+Zl))^2)*Zl;
disp(PL);
scatter(Zl,PL,'filled');
hold on
x = [x, PL];
end
xline(50);
xline(7);
xline(350);
[M,I] = max(x)
```

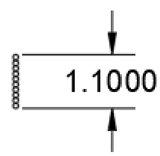
Calculations





WIRE DIAMETER (CM)

COIL RADIUS AND DIAMETER (CM)



COIL CROSS SECTION (CM)

Final Coil Inductance: 50.469 uH

Transformer 1

Boundaries:	~%43.75 ----	%100 ----	~%43.75
Primary Impedance:	7Ω	50Ω	350Ω
Transformer 1 Frequency Range:	160.84Hz	1277.17Hz	5.098Khz

Inductor Impedance Formula: Xl = 2ΠfL
f = frequency
L = Coil Inductance

Coil Impedance at 160.84 Hz: 2Π(160.84)(50.469*10^-6) = .05097748Ω

Impedance Matching Formula: (Primary Turns/Secondary Turns) = sqrt(Primary Impedance/Secondary Impednace)

(100/Secondary Turns) = sqrt(7Ω / .05097748Ω)
Secondary Turns: 9
Final Turn Ratio 100:9

(100/90) = sqrt(50Ω / Secondary Impedance)
Secondary Impedance: 2.853
Coil Frequency at Specific Impedance: 0.405 = 2Πf(50.469*10^-6)
Coil Frequency at Specific Impedance: 1277.17Hz

(100/90) = sqrt(350Ω / Secondary Impedance)
Secondary Impedance: 2.835
Coil Frequency at Specific Impedance: Ω2.835 = 2Πf(50.469*10^-6)
Coil Frequency at Specific Impedance: 8.94 Khz

Normalized based on octave allocations: 5.098 Khz
Secondary Impedance at 5.098 Khz: 1.61578Ω
Primary Impedance at 5.098Khz: Ω199.469
Power Transfer at Primary Impedance: 64%

Transformer 2

Boundaries:	~%43.75 ----	%100 ----	~%43.75
Primary Impedance:	7Ω	50Ω	350Ω
Transformer 1 Frequency Range:	5.098Khz	36.32Khz	328.7Khz

Inductor Impedance Formula: Xl = 2ΠfL
f = frequency
L = Coil Inductance

Coil Impedance at 5.098Khz Hz: 2Π(5098)(50.469*10^-6) = 1.61578Ω
Impedance Matching Formula: (Primary Turns/Secondary Turns) = sqrt(Primary Impedance/Secondary Impednace)

(100/Secondary Turns) = sqrt(7Ω / 1.61578Ω)
Secondary Turns: 48
Final Turn Ratio 100:48

(100/90) = sqrt(50Ω / Secondary Impedance)
Secondary Impedance: 11.52Ω
Coil Frequency at Specific Impedance: 11.52Ω = 2Πf(50.469*10^-6)
Coil Frequency at Specific Impedance: 36.3215 Khz

(100/90) = sqrt(350Ω / Secondary Impedance)
Secondary Impedance: 80.64Ω
Coil Frequency at Specific Impedance: 80.64Ω = 2Πf(50.469*10^-6)
Coil Frequency at Specific Impedance: 254.299824 Khz

Normalized based on octave allocations: 328.7Khz
Secondary Impedance at 328.7 Khz: 104.17Ω
Primary Impedance at 5.098Khz: 452.126Ω
Power Transfer at Primary Impedance: 35.27%

Transformer 3

```
Boundaries:                        ~%43.75 ---- %100 ---- ~%43.75
Primary Impedance:                    7Ω          50Ω         350Ω
Transformer 1 Frequency Range:     328.7Khz    2.397Mhz   21.215Mhz
```

Inductor Impedance Formula: Xl = 2ΠfL
f = frequency
L = Coil Inductance

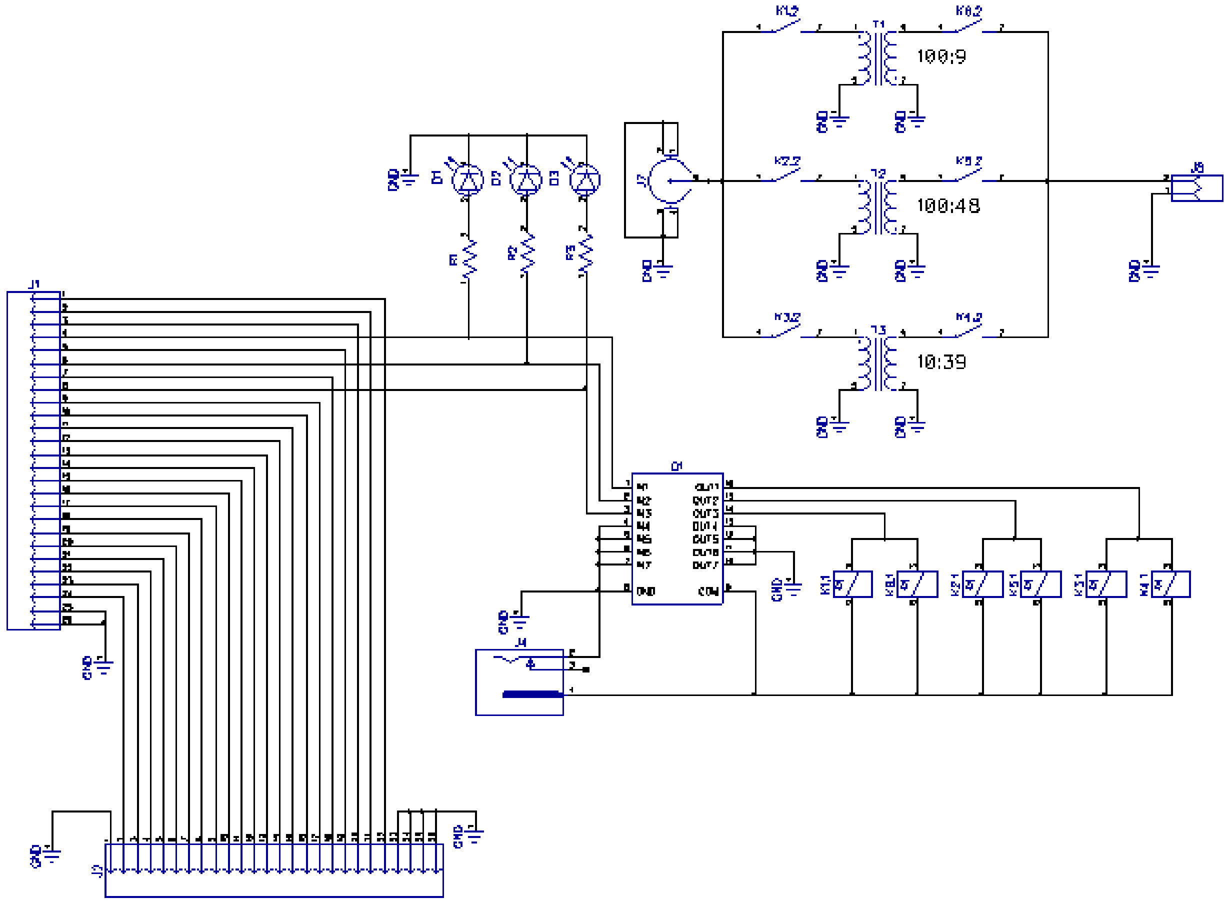
Coil Impedance at 328.7 Khz: 2Π(328.7Khz)(50.469*10^-6) = 104.17Ω
Impedance Matching Formula: (Primary Turns/Secondary Turns) = sqrt(Primary Impedance/Secondary Impedance)

(100/Secondary Turns) = sqrt(7Ω / 104.17Ω)
Secondary Turns: 48
Final Turn Ratio 10:39

(100/90) = sqrt(50Ω / Secondary Impedance)
Secondary Impedance:760.5Ω
Coil Frequency at Specific Impedance: 760.5Ω = 2Πf(50.469*10^-6)
Coil Frequency at Specific Impedance: 2.398 Mhz

Coil Impedance for a Frequency of 21.215Mhz: 6723.9Ω = 2Π(2398251)(50.469*10^-6)
Primary Impedance: 442.07
Power Delivery at this Impedance: %36.51

Lower Bound	Upper Bound	Span		Turn Ratio	~43.75% Max Power	100% Max Power	~43.75% Max Power
160.84Hz	316.95Hz	156.110Hz					
316.95Hz	645.08Hz	328.130Hz					
645.08Hz	1.271KHz	615.920Hz	Transformer 1	100:9	160.84 Hz	1277.17 Hz	5.098 Khz (64%)
1.271KHz	2.587KHz	1.3160KHz					
2.587KHz	5.098KHz	2.511KHz					
5.098KHz	10.376KHz	5.278KHz					
10.376KHz	20.446KHz	10.070KHz					
20.446KHz	41.613KHz	21.1670KHz					
41.613KHz	82.002KHz	40.389KHz	Transformer 2	100:48	5.098 Khz	36.3285 Khz	328.877 Khz (35.27%)
82.002KHz	161.590KHz	79.588KHz					
161.590KHz	328.877KHz	167.287KHz					
328.877KHz	648.071KHz	319.194KHz					
648.071KHz	1.328MHz	680.0KHz					
1.328MHz	2.599MHz	1.271MHz					
2.599MHz	5.289MHz	2.690MHz	Transformer 3	10:39	328.877 Khz	2.39721 Mhz	21.215MHz (36.51%)
5.289MHz	10.424MHz	5.135MHz					
10.424MHz	21.215MHz	10.791MHz					



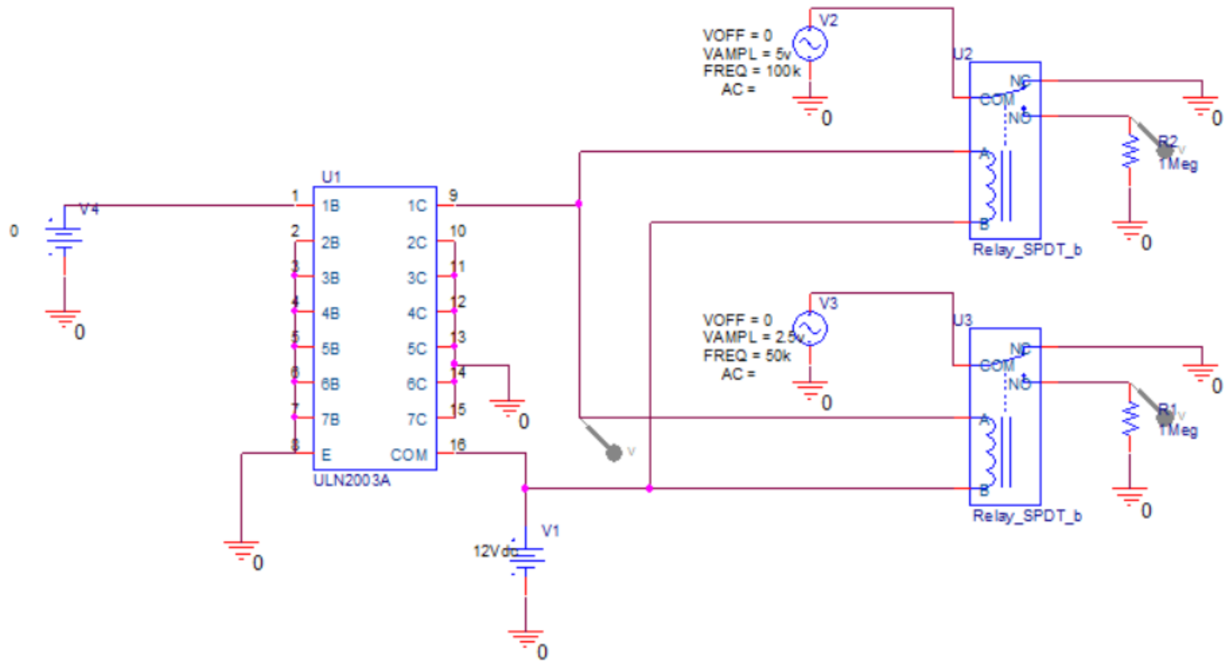
Header J1

PIN	Description	Assignment	FPGA Pin	FPGA pin description	Voltage Level
1	3V3	Pass Through	N/A	N/A	3.3V
2	3V3	Pass Through	N/A	N/A	3.3V
3	DIO0_P	Pass Through	G17	IO_L16P_T2_35 (EXT TRIG)	3.3V
4	DIO0_N	Relays transformer 3	G18	IO_L16N_T2_35	3.3V
5	DIO1_P	Pass Through	H16	IO_L13P_T2_MRCC_35	3.3V
6	DIO1_N	Relays transformer 2	H17	IO_L13N_T2_MRCC_35	3.3V
7	DIO2_P	Pass Through	J18	IO_L14P_T2_AD4P_SRCC_35	3.3V
8	DIO2_N	Relays transformer 1	H18	IO_L14N_T2_AD4N_SRCC_35	3.3V
9	DIO3_P	Pass Through	K17	IO_L12P_T1_MRCC_35	3.3V
10	DIO3_N	Pass Through	K18	IO_L12N_T1_MRCC_35	3.3V
11	DIO4_P	Pass Through	L14	IO_L22P_T3_AD7P_35	3.3V
12	DIO4_N	Pass Through	L15	IO_L22N_T3_AD7N_35	3.3V
13	DIO5_P	Pass Through	L16	IO_L11P_T1_SRCC_35	3.3V
14	DIO5_N	Pass Through	L17	IO_L11N_T1_SRCC_35	3.3V
15	DIO6_P	Pass Through	K16	IO_L24P_T3_AD15P_35	3.3V
16	DIO6_N	Pass Through	J16	IO_L24N_T3_AD15N_35	3.3V
17	DIO7_P	Pass Through	M14	IO_L23P_T3_35	3.3V
18	DIO7_N	Pass Through	M15	IO_L23N_T3_35	3.3V
19	NC	Pass Through	N/A	N/A	3.3V
20	NC	Pass Through	N/A	N/A	3.3V
21	NC	Pass Through	N/A	N/A	3.3V
22	NC	Pass Through	N/A	N/A	3.3V
23	NC	Pass Through	N/A	N/A	3.3V
24	NC	Pass Through	N/A	N/A	3.3V
25	GND	Pass Through	N/A	N/A	3.3V
26	GND	Pass Through	N/A	N/A	3.3V

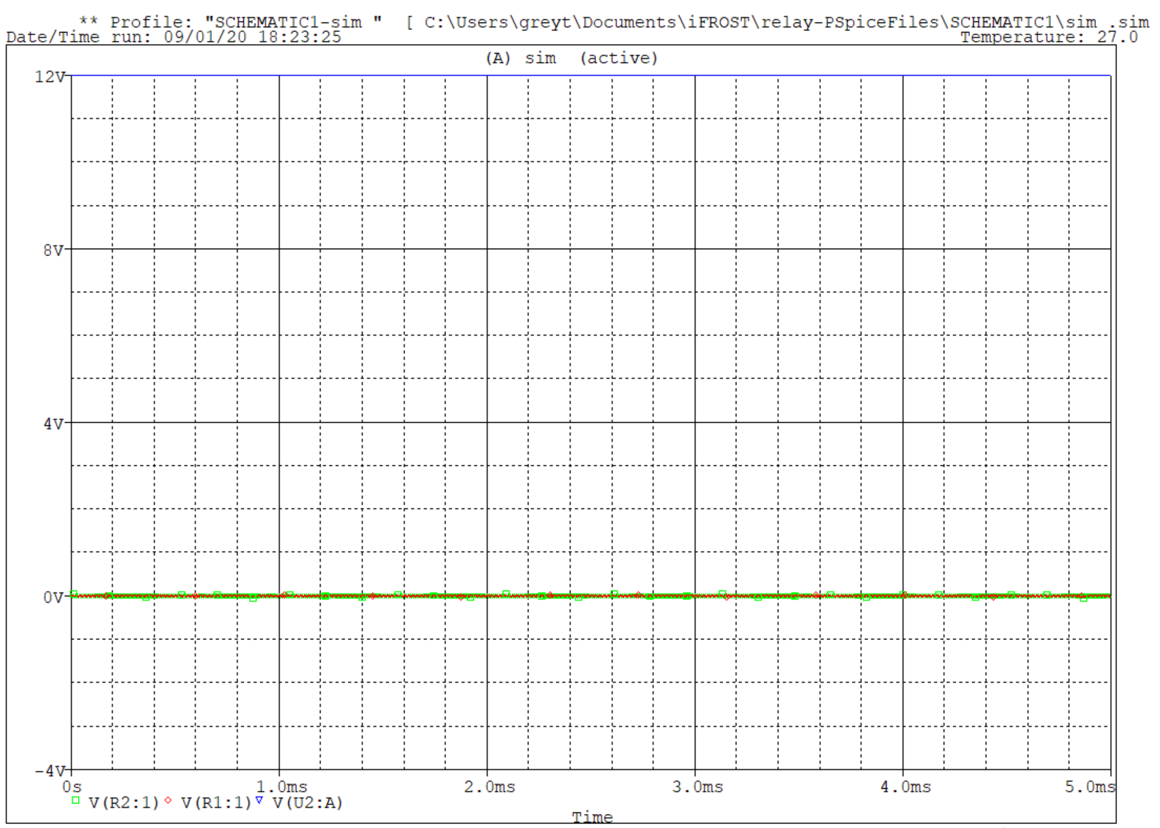
Header J2

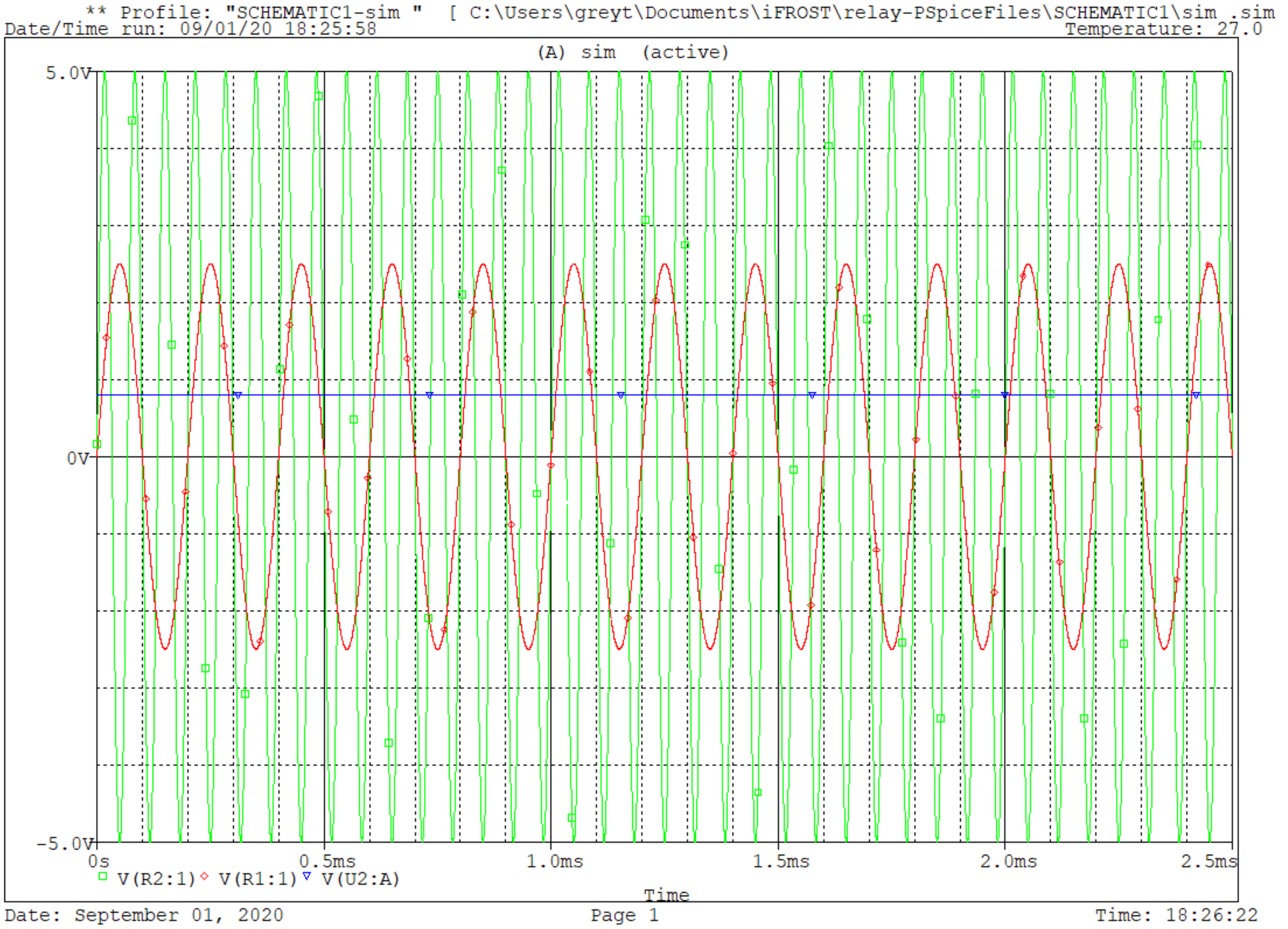
PIN	Description	FPGA Pin	FPGA pin description	Voltage Level
1	GND			
2	NC	N/A	N/A	N/A
3	NC	N/A	N/A	N/A
4	NC	N/A	N/A	N/A
5	NC	N/A	N/A	N/A
6	NC	N/A	N/A	N/A
7	NC	N/A	N/A	N/A
8	DIO7_N	M15	IO_L23N_T3_35	3.3V
9	DIO7_P	M14	IO_L23P_T3_35	3.3V
10	DIO6_N	J16	IO_L24N_T3_AD15N_35	3.3V
11	DIO6_P	K16	IO_L24P_T3_AD15P_35	3.3V
12	DIO5_N	L17	IO_L11N_T1_SRCC_35	3.3V
13	DIO5_P	L16	IO_L11P_T1_SRCC_35	3.3V
14	DIO4_N	L15	IO_L22N_T3_AD7N_35	3.3V
15	DIO4_P	L14	IO_L22P_T3_AD7P_35	3.3V
16	DIO3_N	K18	IO_L12N_T1_MRCC_35	3.3V
17	DIO3_P	K17	IO_L12P_T1_MRCC_35	3.3V
18	DIO2_P	J18	IO_L14P_T2_AD4P_SRCC_35	3.3V
19	DIO1_P	H16	IO_L13P_T2_MRCC_35	3.3V
20	DIO0_P	G17	IO_L16P_T2_35 (EXT TRIG)	3.3V
21	3V3	N/A	N/A	3.3V
22	3V3	N/A	N/A	3.3V
23	GND			
24	GND			
25	GND			
26	GND			

Relay Driver Sim

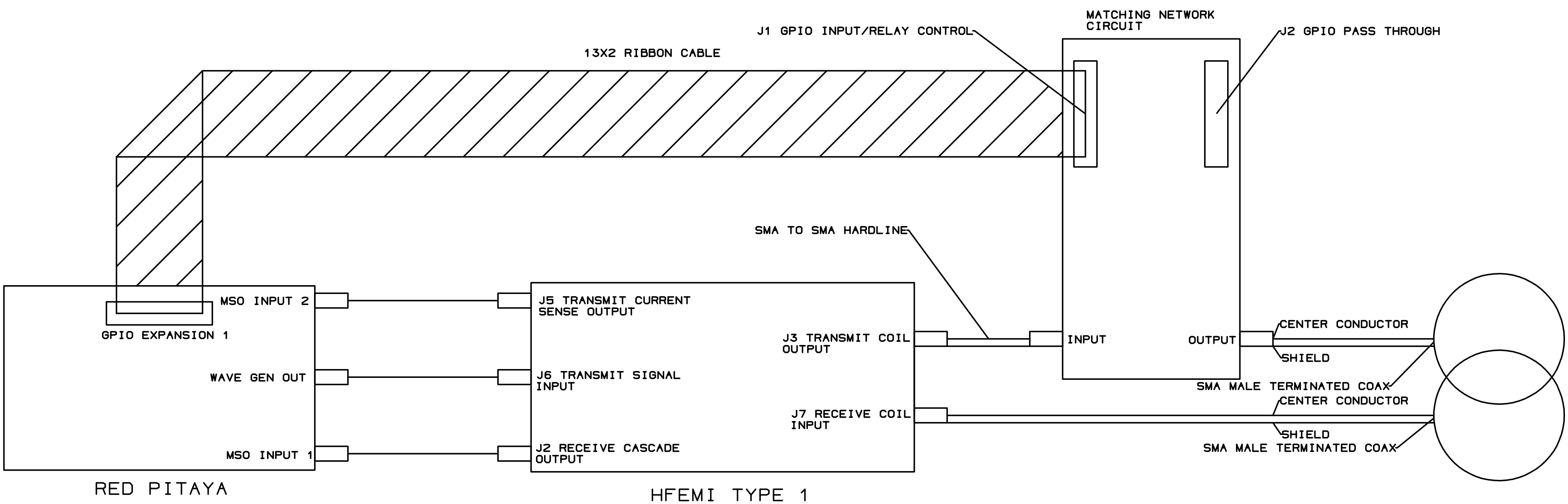


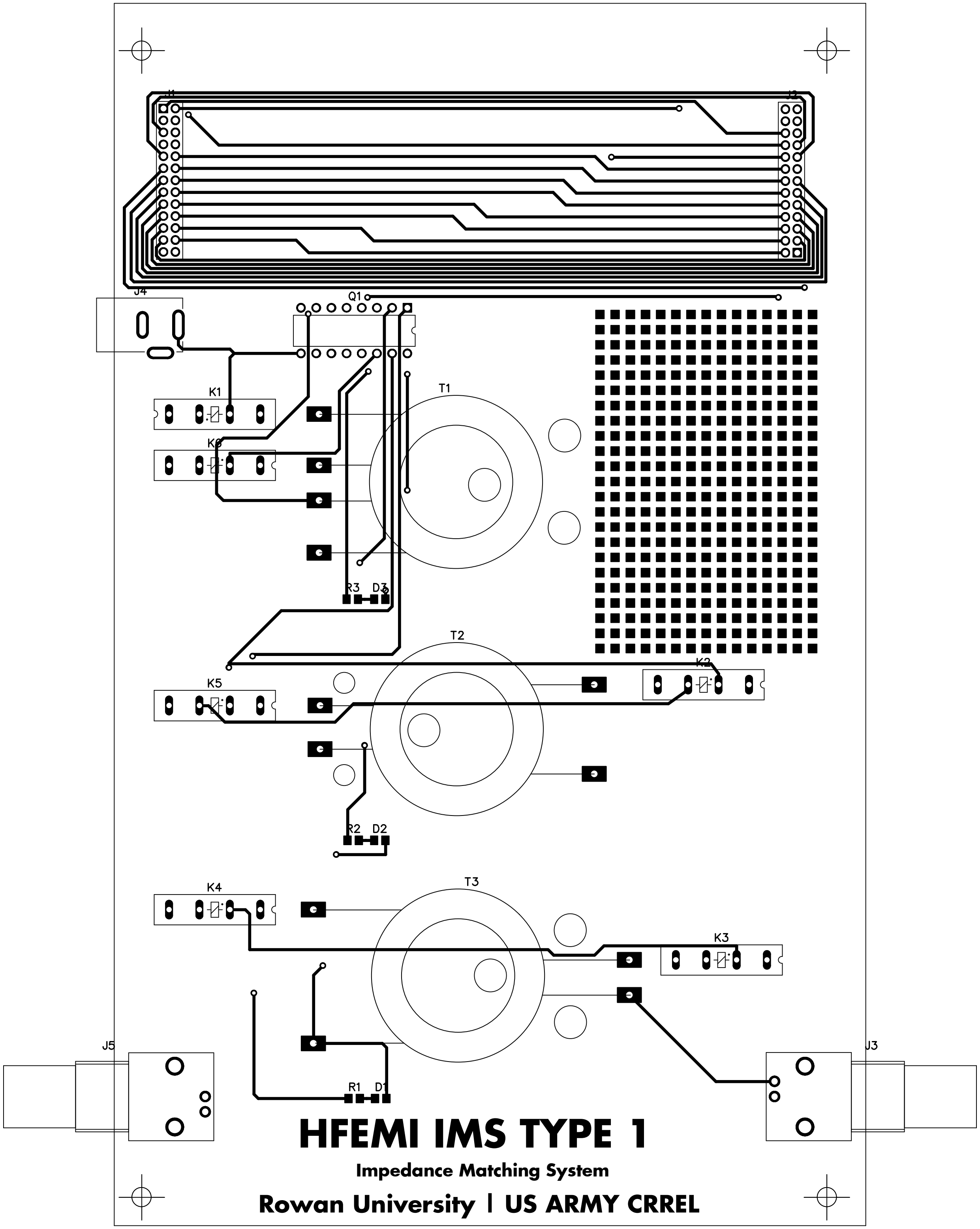
The relay circuit was simulated to ensure that driver IC could drive 2 relays per channel. Relay J2 was fed by a 100KHz sin source, relay J3 was fed by a 50KHz sin source. When the voltage to pin 1B is 0 the output should be 0, when voltage to pin 1B is 3.3v the output of each relay should be a sin waves with an amplitude of 5v and 2.5v respectively and a frequency of 100Khz and 50KHz respectively.

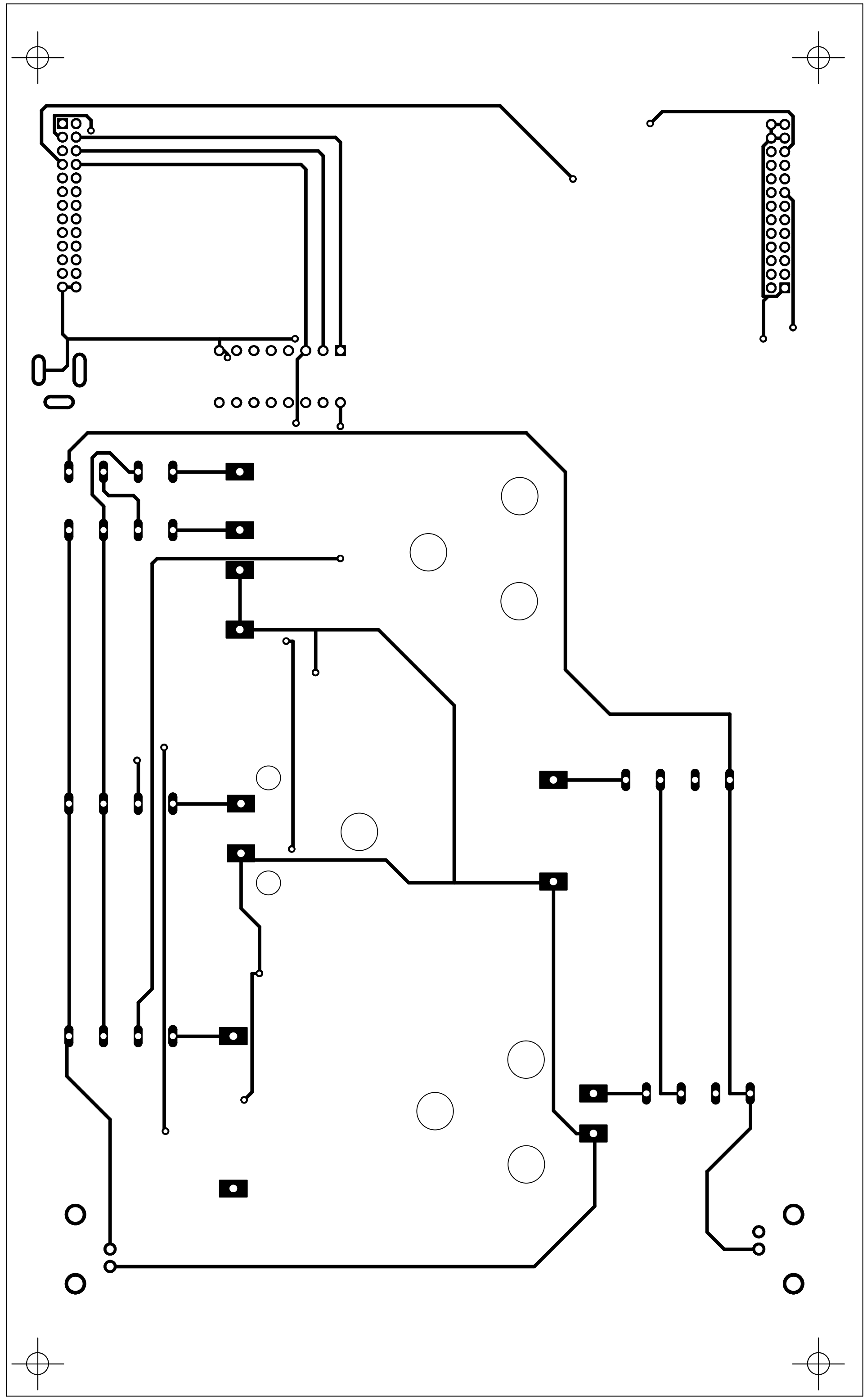




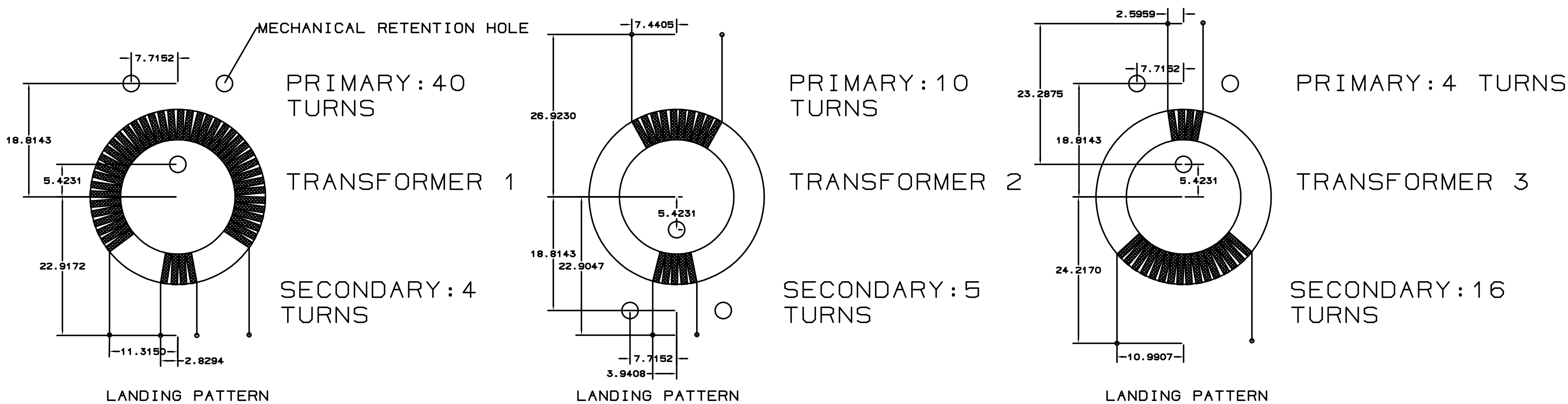
Red Trace: J3 output
Green Trace: J2 output
Blue Trace: Relay driver common


13X2 RIBBON CABLE
J1 GPIO INPUT/RELAY CONTROL
MATCHING NETWORK CIRCUIT
J2 GPIO PASS THROUGH
SMA TO SMA HARDLINE
MSO INPUT 2
GPIO EXPANSION 1
WAVE GEN OUT
MSO INPUT 1
J5 TRANSMIT CURRENT SENSE OUTPUT
J6 TRANSMIT SIGNAL INPUT
J2 RECEIVE CASCADE OUTPUT
J3 TRANSMIT COIL OUTPUT
J7 RECEIVE COIL INPUT
INPUT
OUTPUT
CENTER CONDUCTOR
SHIELD
SMA MALE TERMINATED COAX
CENTER CONDUCTOR
SHIELD
SMA MALE TERMINATED COAX
RED PITAYA
HFEMI TYPE 1


J4
Q1
K1
K6
T1
R3
D3
T2
K2
K5
R2
D2
K4
T3
K3
J5
J3
R1
D1
HFEMI IMS TYPE 1
Impedance Matching System
Rowan University | US ARMY CRREL



TRANSFORMER CORE MECHANICAL DESIGN (ALL UNITS MM)
BASED ON AMIDON FT-144-61/ OD:29 / ID:19 / HT 7.5



61 Material and is designed for inductive applications up to 25 MHz and also suppresses noise frequencies from 200 MHz to 1000 MHz

SHOPPING CART

This is not an invoice

09-Sep-20 11:58:46

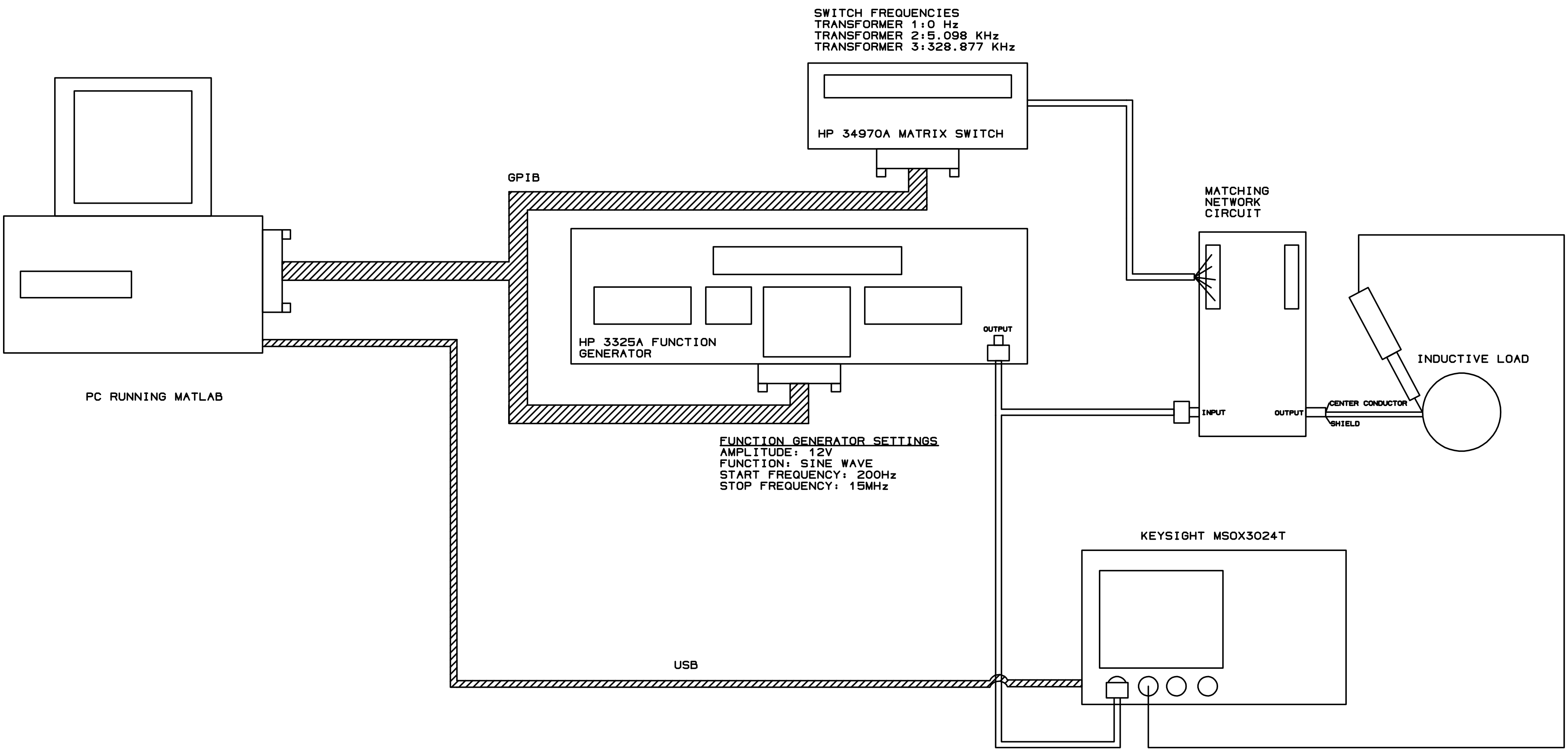
	Mouser #	Mfr. #	Manufacturer	Customer #
1	511-ULN2003A	ULN2003A	STMicroelectronics	
2	755-SML-H12U8TT86C	SML-H12U8TT86C	ROHM Semiconductor	
3	934-HE3621A1250	HE3621A1250	Littelfuse	
4	490-PJ-002A	PJ-002A	CUI Devices	
5	517-4816-3000-CP	4816-3000-CP	3M	
6	649-76385-313LF	76385-313LF	FCI / Amphenol	
7	523-31-5637	031-5637	Amphenol	
8	71-CRCW0805-50	CRCW080550R0FKTA	Vishay	
9	534-4946	4946	Keystone Electronics	
10	534-9605	9605	Keystone Electronics	

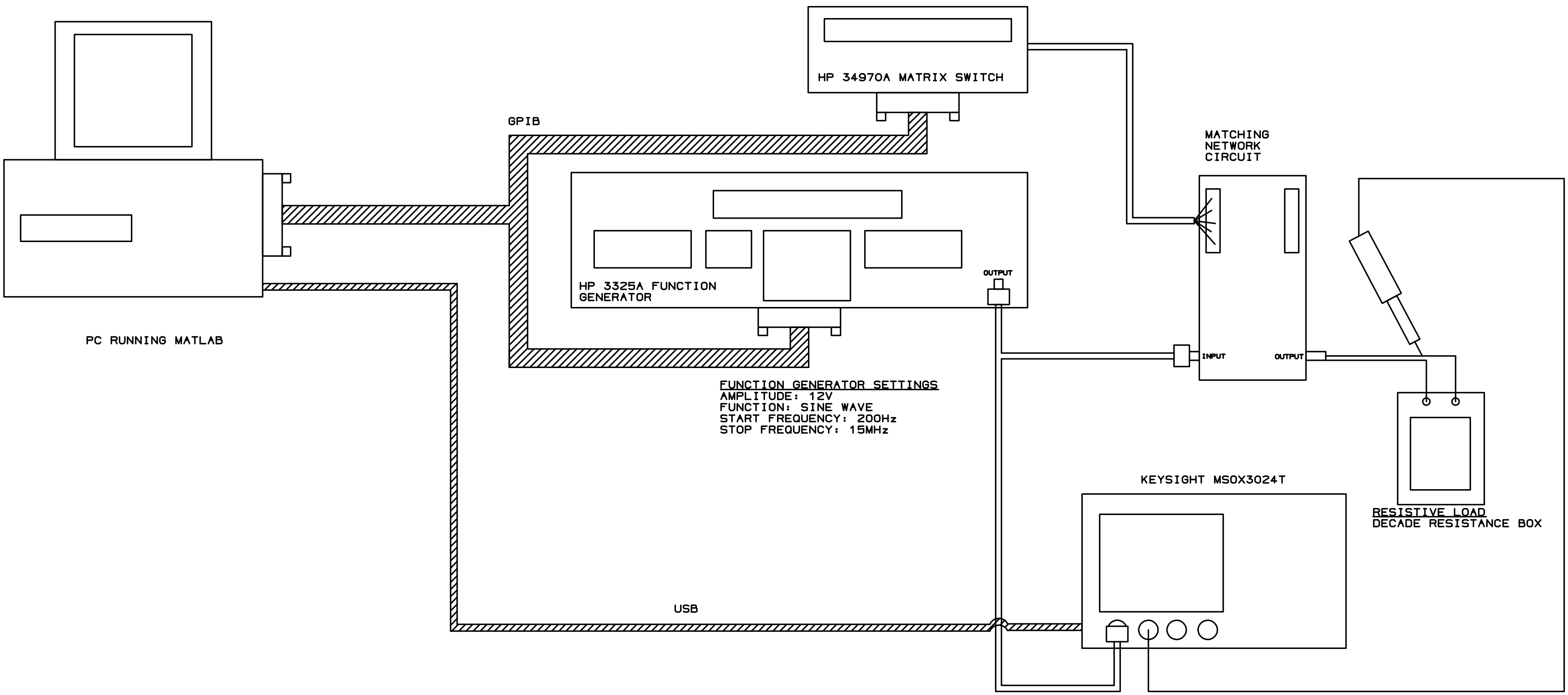
Description	RoHS
Darlington Transistors Seven NPN Array	RoHS Compliant
Standard LEDs - SMD Red 620nm 40mcd 2.2V; 20mA 0805	RoHS Compliant
Reed Relays REED RELAY	RoHS Compliant
DC Power Connectors Power Jacks	RoHS Compliant
IC & Component Sockets 16P DUAL WIPE DIPSKT	RoHS Compliant
Headers & Wire Housings 26P VERT DR HDR AU	RoHS Compliant
RF Connectors / Coaxial Connectors RIGHT ANGLE PCB JACK	RoHS Compliant By Exemption
Thick Film Resistors - SMD 1/8watt 50ohms 1% Non Std Qt Req'd	No
Standoffs & Spacers M/F NYLON STANDOFF 4-40 1.00 L	RoHS Compliant
Screws & Fasteners 1/4 4-40 Nylon Hex M SCREW NUT	RoHS Compliant

Lifecycle	Order Qty.	Price (USD)	Ext.: (USD)
	5	$0.51	$2.55
	20	$0.283	$5.66
	10	$1.79	$17.90
	5	$0.59	$2.95
	2	$0.53	$1.06
	3	$2.34	$7.02
	4	$5.18	$20.72
	50	$0.279	$13.95
	10	$0.566	$5.66
	11	$0.124	$1.36

Merchandise Total:

Shipping Charge:


SWITCH FREQUENCIES
TRANSFORMER 1:0 Hz
TRANSFORMER 2:5.098 KHz
TRANSFORMER 3:328.877 KHz
HP 34970A MATRIX SWITCH
GPIB
MATCHING
NETWORK
CIRCUIT
HP 3325A FUNCTION
GENERATOR
OUTPUT
INPUT
OUTPUT
CENTER CONDUCTOR
SHIELD
INDUCTIVE LOAD
PC RUNNING MATLAB
FUNCTION GENERATOR SETTINGS
AMPLITUDE: 12V
FUNCTION: SINE WAVE
START FREQUENCY: 200Hz
STOP FREQUENCY: 15MHz
KEYSIGHT MSOX3024T
USB


HP 34970A MATRIX SWITCH
GPIB
MATCHING
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KEYSIGHT MSOX3024T
RESISTIVE LOAD
DECADE RESISTANCE BOX
USB