HF Power Amplifier (Reference Design Guide)

RFID Systems / ASP

1.) Scope

Shown herein is a HF power amplifier design with performance plots. As every application is different and unique, this application is given as an example to guide the user to a successful development effort.

Naturally with any design, proper PCB layout is important. Keep circuit outputs from feeding back into their respective inputs, use proper PCB grounding; **do not split analog and digital grounds.**

With RF output levels at 4 watts, the output voltage level is 40 Vp-p, hence it is recommended to use 0805 capacitors with voltage ratings at 100 V minimum. Only components at the MOSFET output need to be at the higher voltage ratings. The recommended voltage for all 0603 components is 50V.

2.) Description

Shown in Figure 2 is a HF Power Amplifier reference design. The design contains a TRF7960 reader, MSP430 micro-processor for reader control, a USB interface for external PC applications, and a HF power amplifier. The reference design requires a +15 V DC source @ 1 amp max to feed two internal regulators, one regulator at +12 volts to power the RF power amplifier, and a second regulator at +5 volts to power the reader, MSP430, & USB circuits. External to the HF Power Amplifier is a 30 by 40 cm antenna (not shown). Typical read range is 47 cm (18.5 inches) using a credit card size tag.

Note that in this application, the antenna is tuned slightly off frequency. This is to prevent the RF carrier from saturating or desensitizing receiver circuits during transmission.

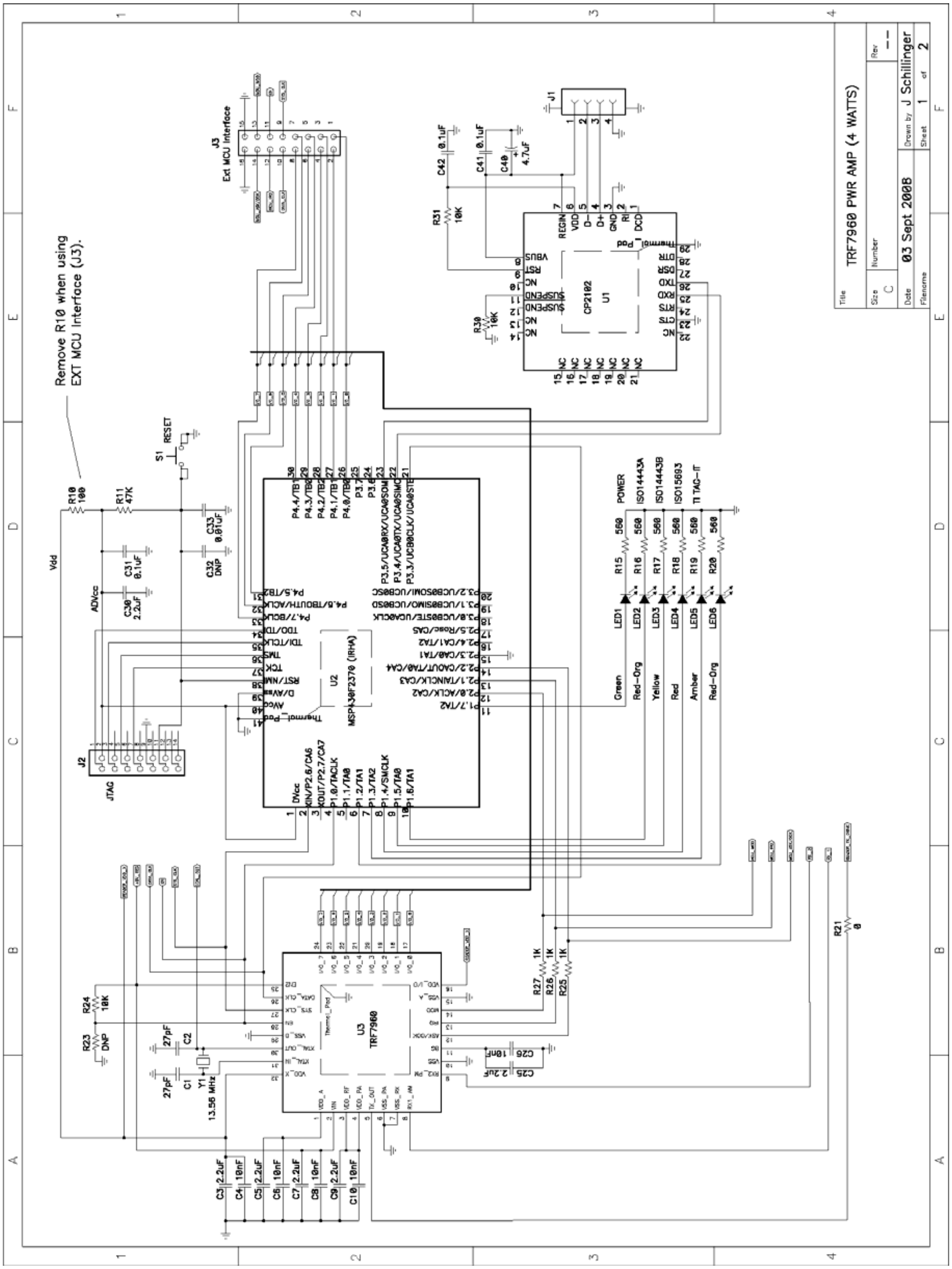


Figure 2A
TRF7960 HF Power Amplifier

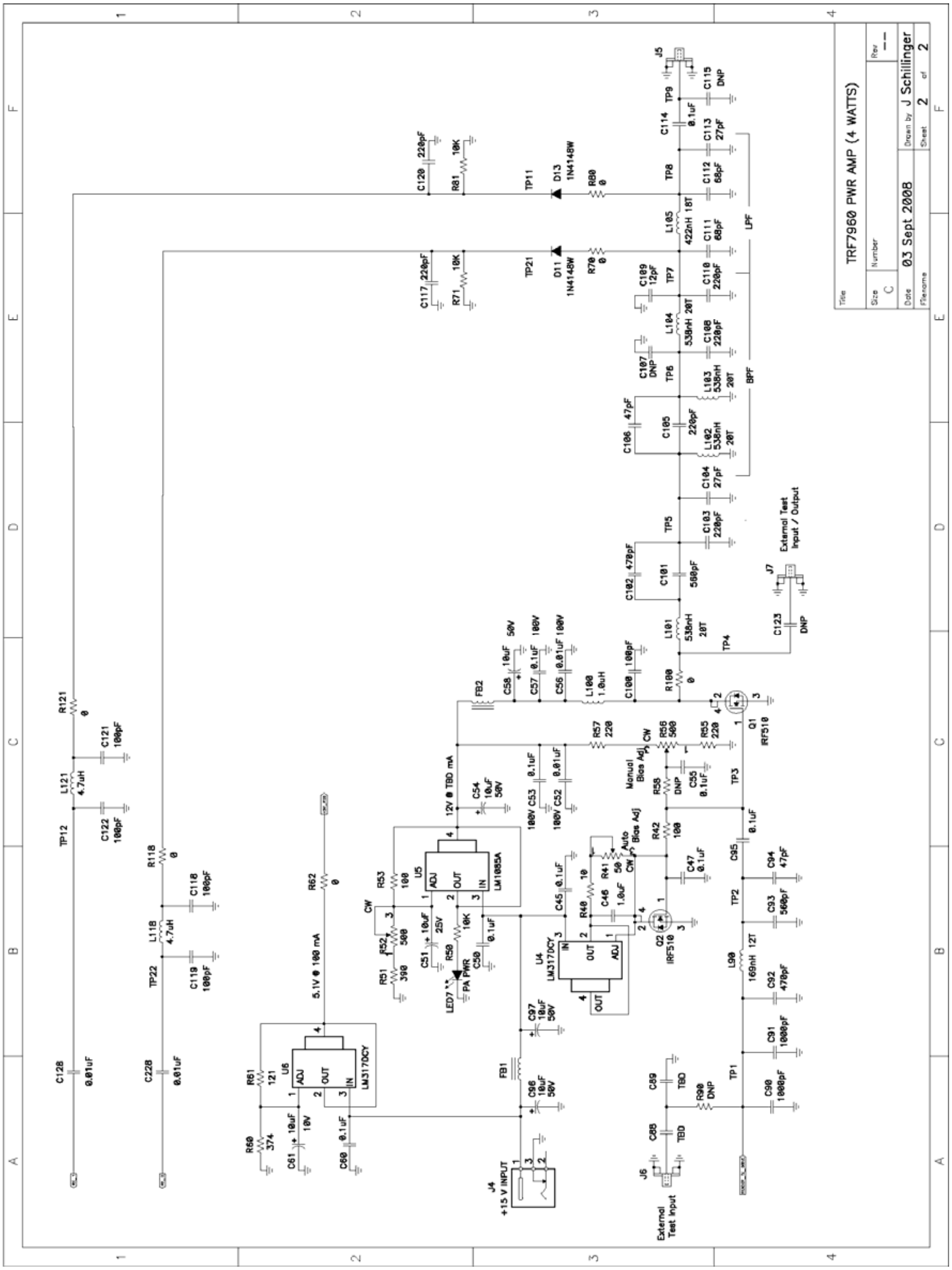


Figure 2B
TRF7960 HF Power Amplifier

3.) Performance Specifications

DC Power (Assembly)	+15 V @ 675 mA (typical)
Pwr Amp	+12 V @ 525 mA (typical)
Reader & Dig Ckts	+5 V @ 150 mA (typical)
RF Power	+36 dBm (4 watts)
2^{nd} Harmonic	25 dBc (+10 dBm typical)

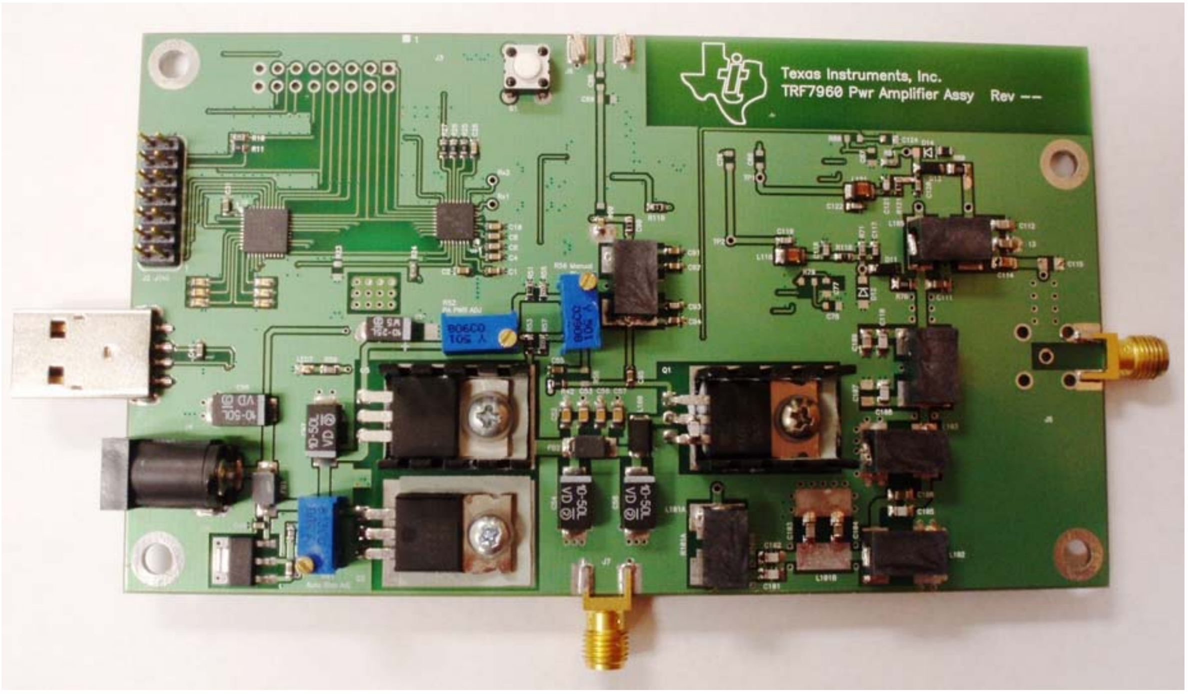
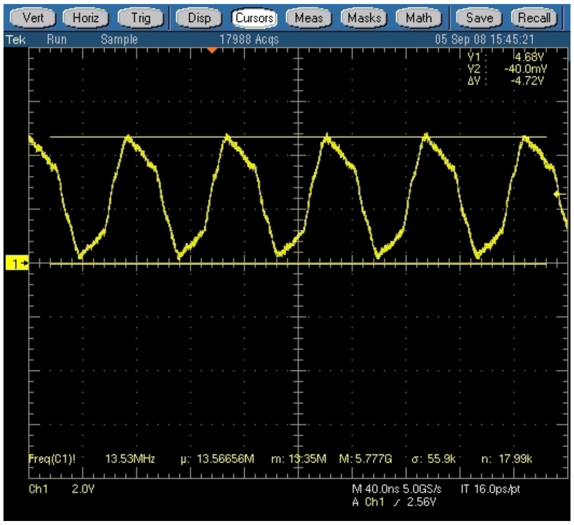


Figure 3
HF RFID Power Amplifier

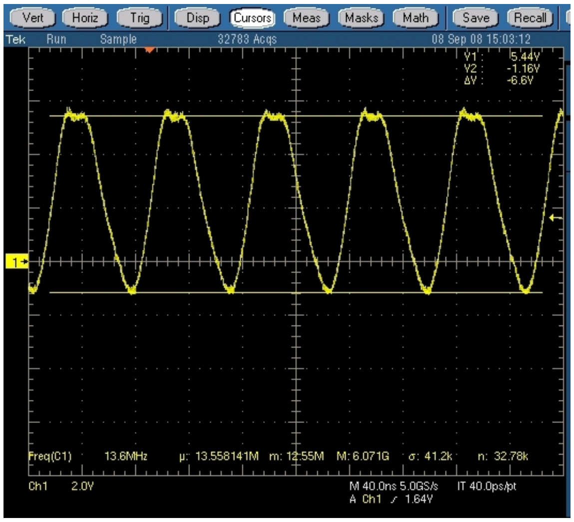
4.) Performance Plots

4.1) MOS FET Gate Circuit

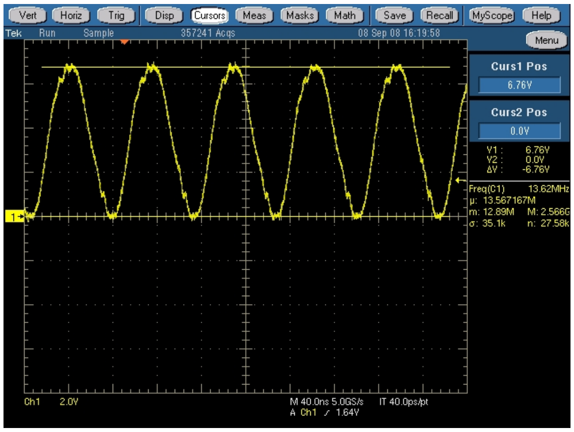
The reader's Tx output (U3-5) is 4 ohms with a square wave output. A LPF is used to transform the reader output impedance to the MOS FET (Q1) gate impedance. With reference to the schematic shown in Figure 2B, TP1 is the reader output (approx 4.5 Vp-p), which is low pass filtered to TP2. The increased voltage level at TP2 is due to an impedance change as the FET's gate impedance is 14-j26. A 0.1 uF capacitor AC couples the signal to the gate of Q1 (TP3).



TP1
Reader PA Output (pin 5) (4.5 Vp-p)



TP2
Gate LPF Output (6.6 Vp-p)



TP3
Gate Drive (6.7 Vp-p)

4.1) MOS FET Gate Circuit (continued)

Two gate bias circuits are available, manual & auto bias adjust circuits. Placement of a 100 ohm resistor at R58 selects the manual bias adjust while placement of a 100 ohm resistor at R42 selects the auto bias adjust. Likewise potentiometer R56 sets the manual bias adjustment while potentiometer R41 sets the auto bias adjustment. Typically the gate bias is set for 3.6 ± 0.2 volts. Ideally, the gate voltage should be set such that the AC signal drive stays above ground.

Regulator U4 is configured as a constant current regulator. MOSFET Q2 changes the current from U4 to a voltage, which in turn sets a bias voltage at the gate of Q1. The advantage here is that Q2 will automatically adjust the gate bias to Q1 as needed to correct for ambient temperature effects.

4.2) Power Amplifier

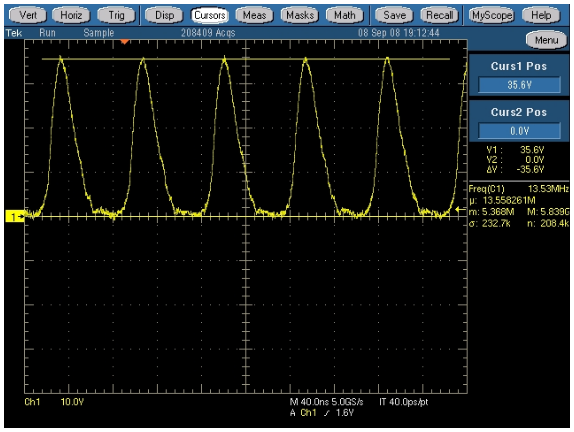
Potentiometer R52 is used to set the drain voltage to power FET Q1, which in turn sets the desired output power level. The out power level is adjustable from 1 to 4 watts by setting potentiometer R52.

Series inductor L101, together with series capacitors C101 & C102, and shunt capacitors C103 & C104 match the drain of Q1 to 50 ohms.

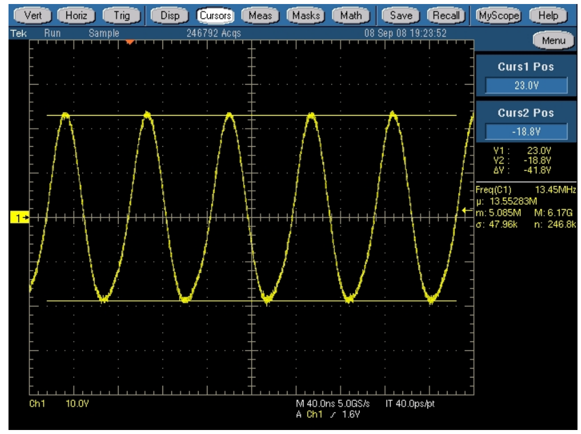
Inductor L102, L103, and capacitors C105 & C106 form a HPF with a 12MHz corner frequency. Inductor L104, and capacitors C108 & C110 form a LPF with a 15 MHz corner frequency. Together these two filters form a BPF. The output filter is a low pass filter consisting of L105 and C108, C111, C112, & C113. The output LPF provides a 50 ohm filter with a 45 deg phase shift. The 45 deg phase shift is necessary for AM & PM circuit detection within the reader’s (U3) internal receiver circuits.

Signal captures of power amplifier’s test points are given herein (TP4 thru TP9).

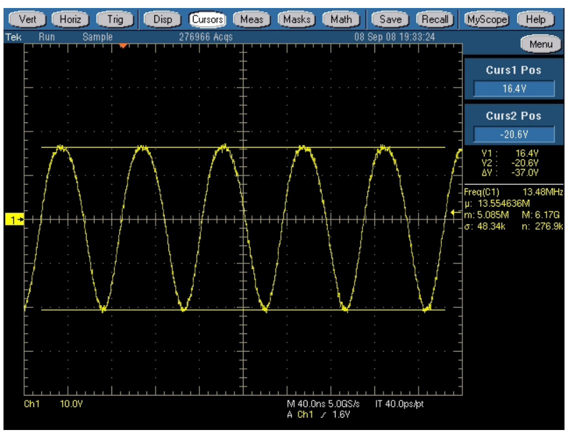
4.2) Power Amplifier (continued)



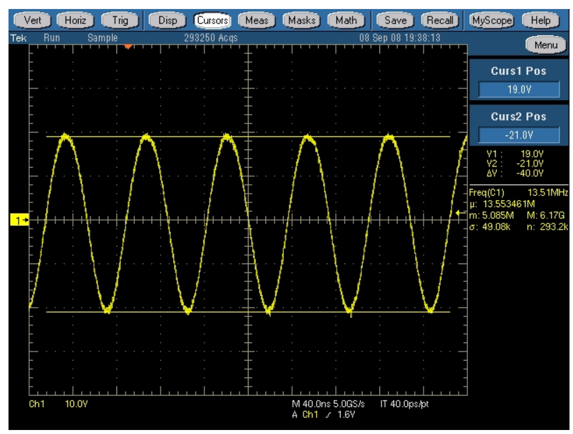
TP4
PA Drain (35.6 Vp-p)



TP5
Input to HPF (41.8 Vp-p)

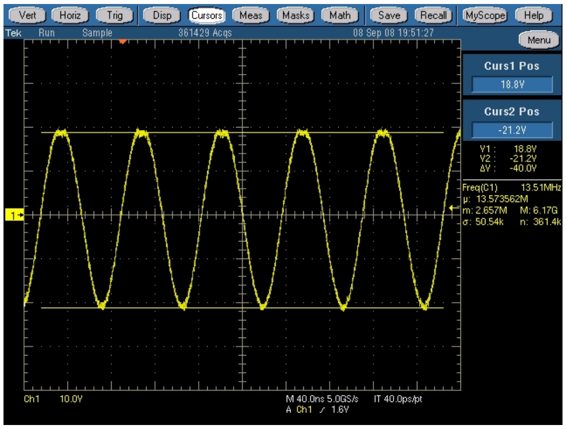


TP6
Input to LPF = 37.0 Vp-p

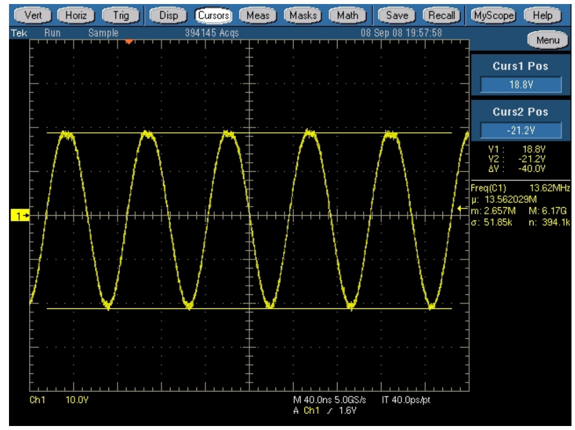


TP7
Input to PA / Rx Final LPF = 40.0 Vp-p

4.2) Power Amplifier (continued)



TP8
PA Output @ C113 = 40.0 Vp-p



TP9
PA Output @ C115 = 40.0 Vp-p

Note, for a +36 dBm signal (or 4 watts), the expected output voltage should be 40 Vp-p when loaded with a 50 ohm load. This mathematically shown as follows:

4.2) Power Amplifier (continued)

Shown in Figure 4.2 is the Tx output spectrum with related harmonics. A 20 dB attenuator is utilized at the spectrum analyzer's input to protect the analyzer from any damage.

Ref: MFg = JFW, P/N = 50FHC-020-20 20 dB @ (20 watts)

Hence when calculating the output power, 20 dB is added to the spectrum analyzer reading.

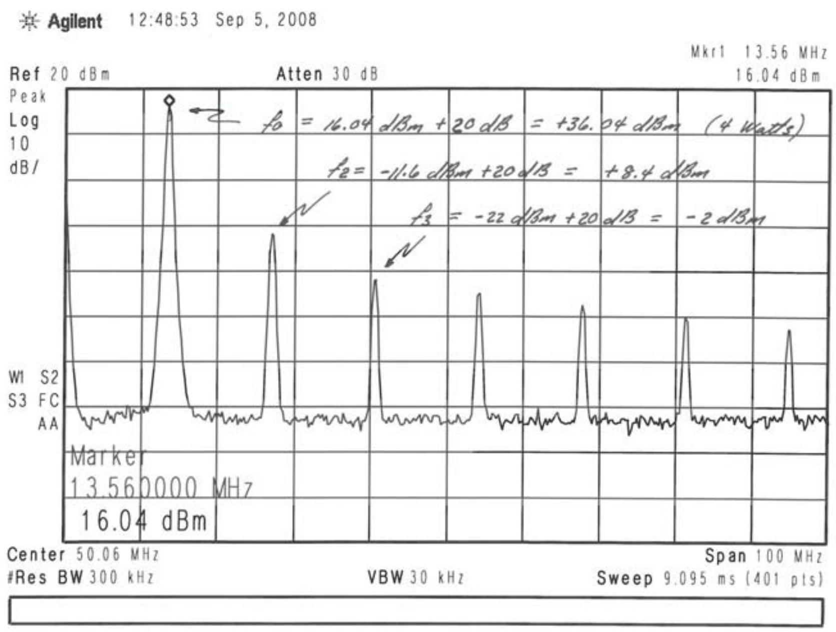


Figure 4.2
Output Spectrum

Shown in Figure 3 is the Tx output spectrum with related harmonics.

$$V_{RMS} = \frac{40.0\ Vp\text{-}p}{2*\sqrt{2}} = \frac{40}{2.828} = 14.14\ V_{RMS}$$

$$Pwr = \frac{(V_{RMS})^2}{R} = \frac{(14.14)^2}{50} = \frac{199.93}{50} = 3.998792\ Watts = \frac{3.998792\ W}{1*10^{-3}\ W} = 3998.792\ mW$$

$$Pwr\ dBm = 10*Log\frac{(3998.792\ mW)}{1\ mW} = +36\ dBm$$

4.3) Receive Signals

4.3.1) PM to AM Detector

Both transmit & received signals share a common LPF (L105 & shut caps) section which provides a fixed 45 deg phase shift for external AM detection circuit D11. As the transmit signal passes through this filter, it is phase shifted 45 degrees. Like wise the received tag responds with its 13.56 MHz signal is also phase shifted by L105, which in turn yields a total phase shift of 90 degrees to diode D11.

Note that when measuring the phase shift across inductor L105 it is important the output load is terminated into a 50 resistive load. Using an antenna load will yield an improper measurement as its load is reactive.

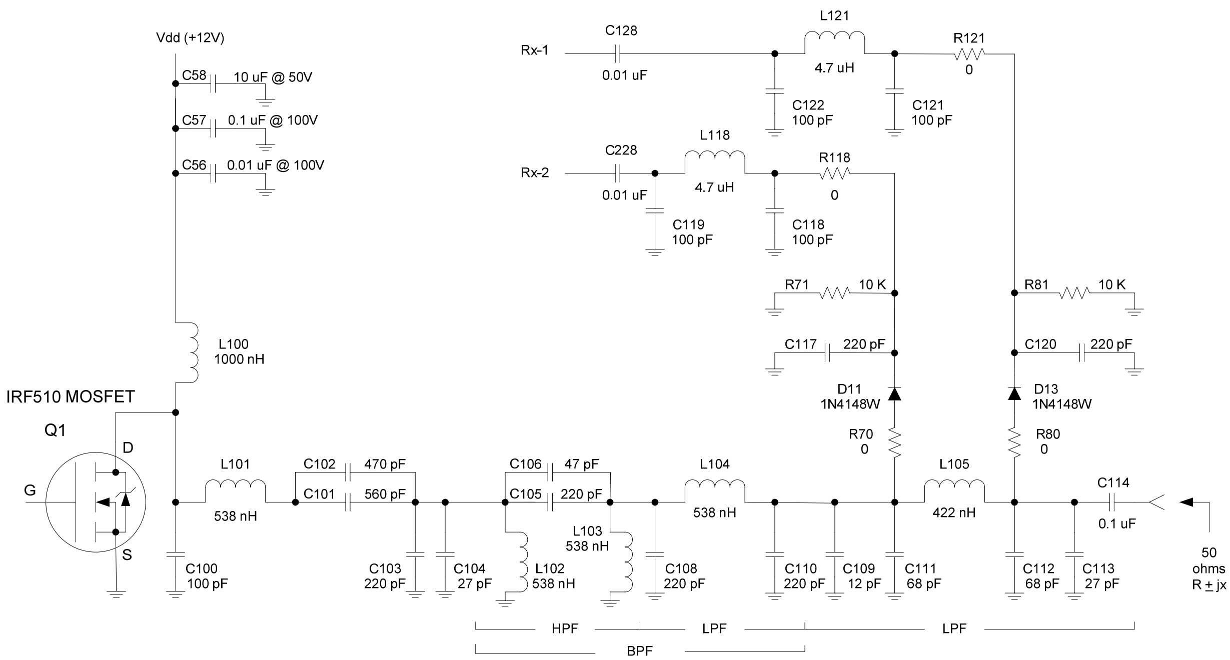


Figure 4.3.1
External Detector Circuits

Passive RF detectors are used to attenuate the RF carrier signal while providing a detected AM sub-carrier signal; this signal is further low pass filtered to each receiver input.

4.3.2) PM to AM Detector (continued)

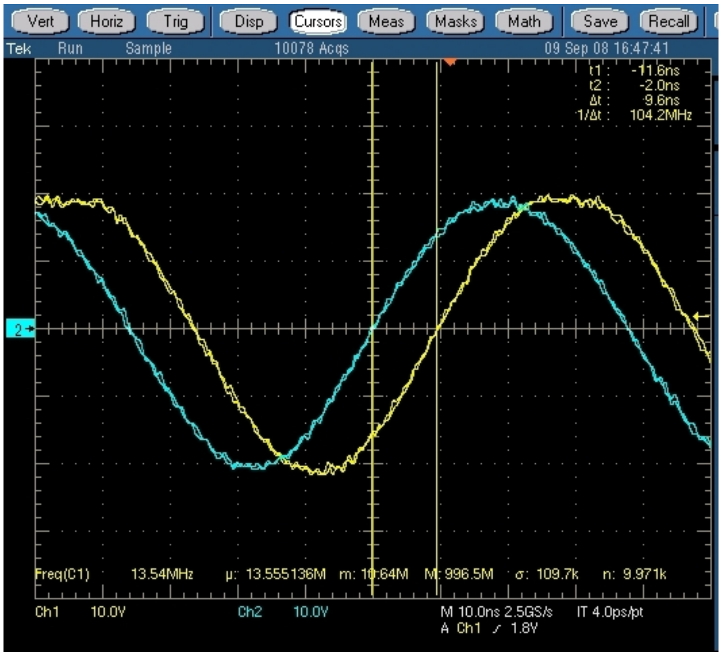


Figure 4.3.2
Rx phase shift (9.6 ns)

Calculating the measured phase is shown as follows:

$$\text{Time} = \frac{1}{\text{freq}} = \frac{1}{13.56 * 10^{6}} = 7.3746313 * 10^{-8} = 73.7 * 10^{-9} = 74\,\text{ns}$$

Given:	360 deg	=	74 ns
Therefore:	180 deg	=	37 ns
	90 deg	=	18 ns
	45 deg	=	9 ns

$$\text{Or} \quad \frac{73.746313 * 10^{-9}\ \text{sec}}{360\ \ \text{deg}} = 2.04851 * 10^{-10} = 0.204851 * 10^{-9} = 0.2048\,\text{ns / deg}$$

In this example, given a measured delay of 9.6 ns would yield

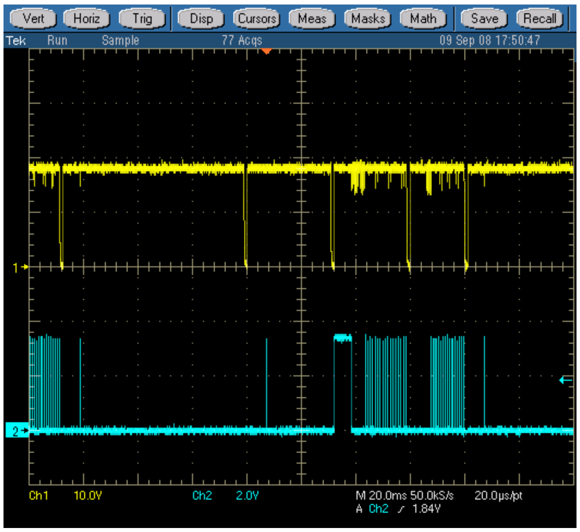
$$??\,\text{deg} = \frac{9.6\,\text{ns}}{0{,}2048\,\text{ns / deg}} = 46.875\,\text{deg}$$

To calculate ns from deg as follows:

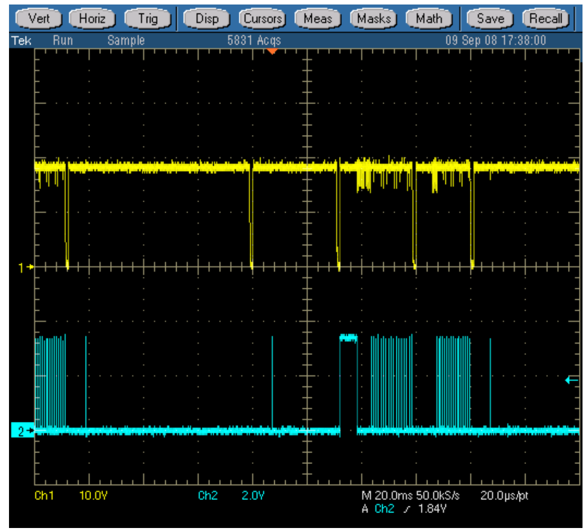
$$??\,\text{ns} = (45\,\text{deg})\,(0.2048) = 9.218\,\text{ns}$$

4.3.3) AM Detector (Rx inputs not configured for sub-carrier input)

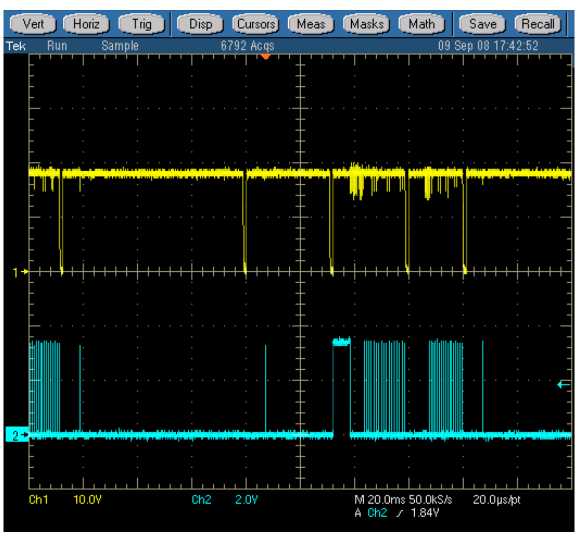
Shown below is the transmitted signal being detected (yellow trace) at TP11 & TP21. The blue trace in each screen shot is the reader IRQ signal used to trigger the display. Note that if the transmitter where operating in a CW mode, both yellow & blue traces would be a flat line.



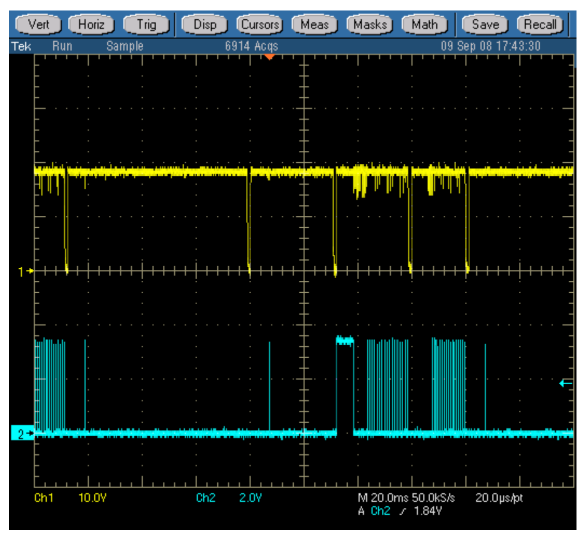
TP11
AM Detector Output (Tx Mode)



TP21
AM Detector Output (Tx Mode)



TP12
Rx-1 LPF Output

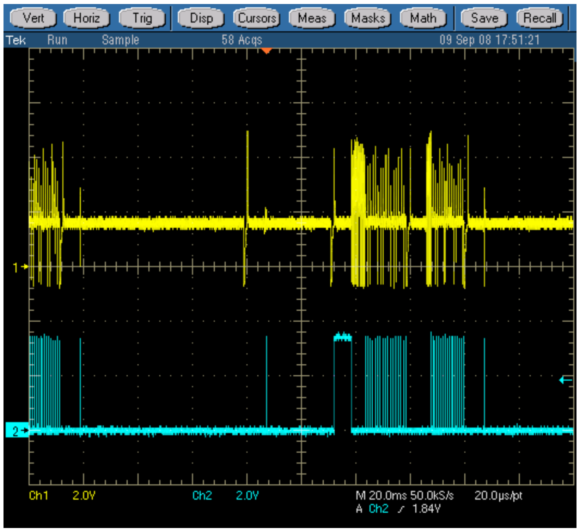


TP22
Rx-2 LPF Output

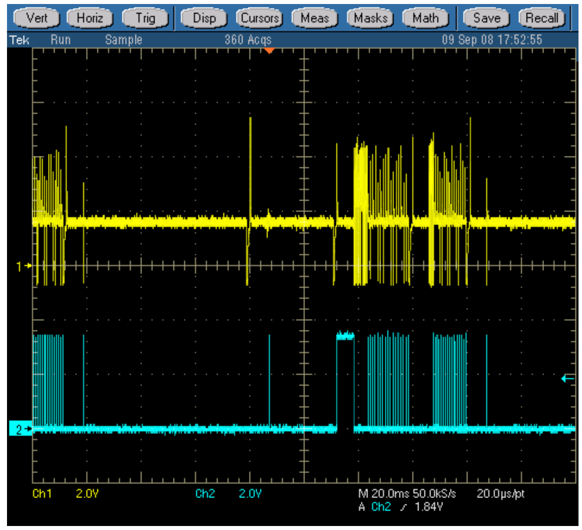
Note that there is no difference shown between Rx-1 & Rx-2 channels, and no difference in pre & post LPF responses.

4.3.3) AM Detector (Rx inputs not configured for sub-carrier input) (continued)

Shown below are the signal inputs to Rx_1 & Rx_2 at the reader pins (8 & 9). Note that voltage scale has changed to 2 V per division while received signal noise has increased. The additional noise is from the reader's receive pins and is normal.



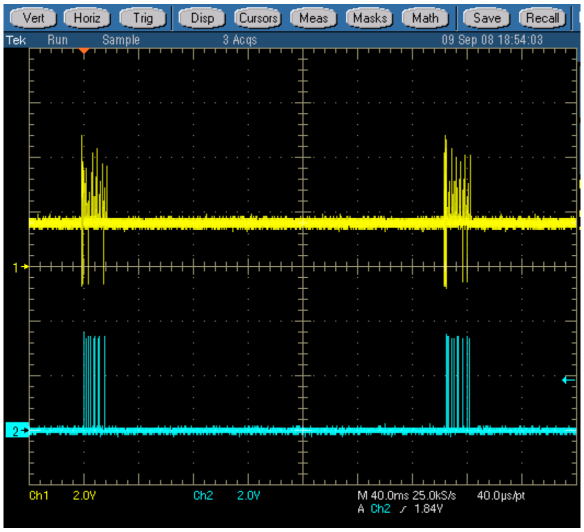
RX_1
Rx_1 AM Input



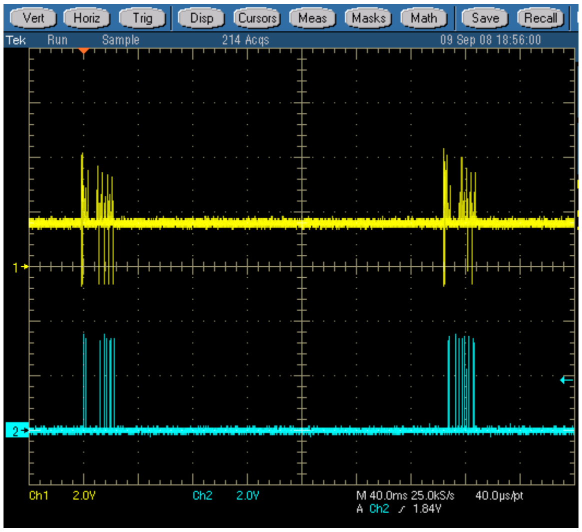
RX_2
Rx_2 PM Input

4.3.4) AM Detector (Rx inputs configured for sub-carrier input)

In the following plots, the GUI is connected to the USB port & the Regulator & I/O Control register is set from 87 to C7. Setting the Regulator & I/O Control register to C7 sets bit B6 to ”1”, which configures the reader receive inputs for an external detected sub-carrier signal (top trace). The bottom trace is the reader IRQ signal.

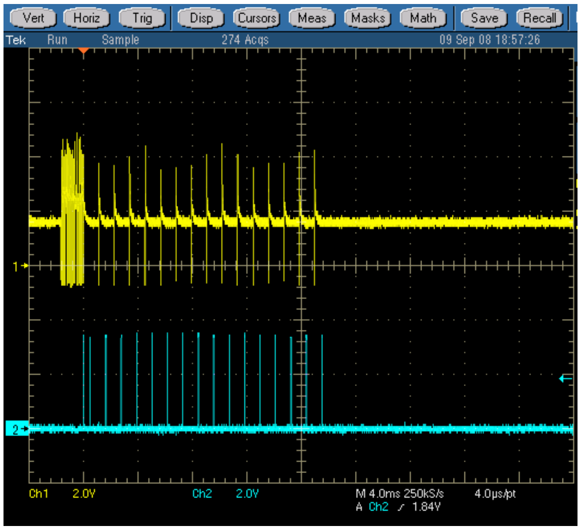


Receiver Inputs (No Tag 1 of 2)

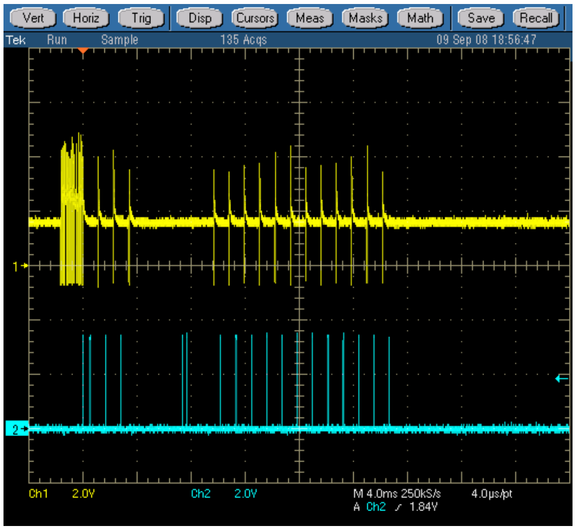


Receiver Inputs (Tag 1 of 2)

The following pictures show the receiver inputs in more detail.



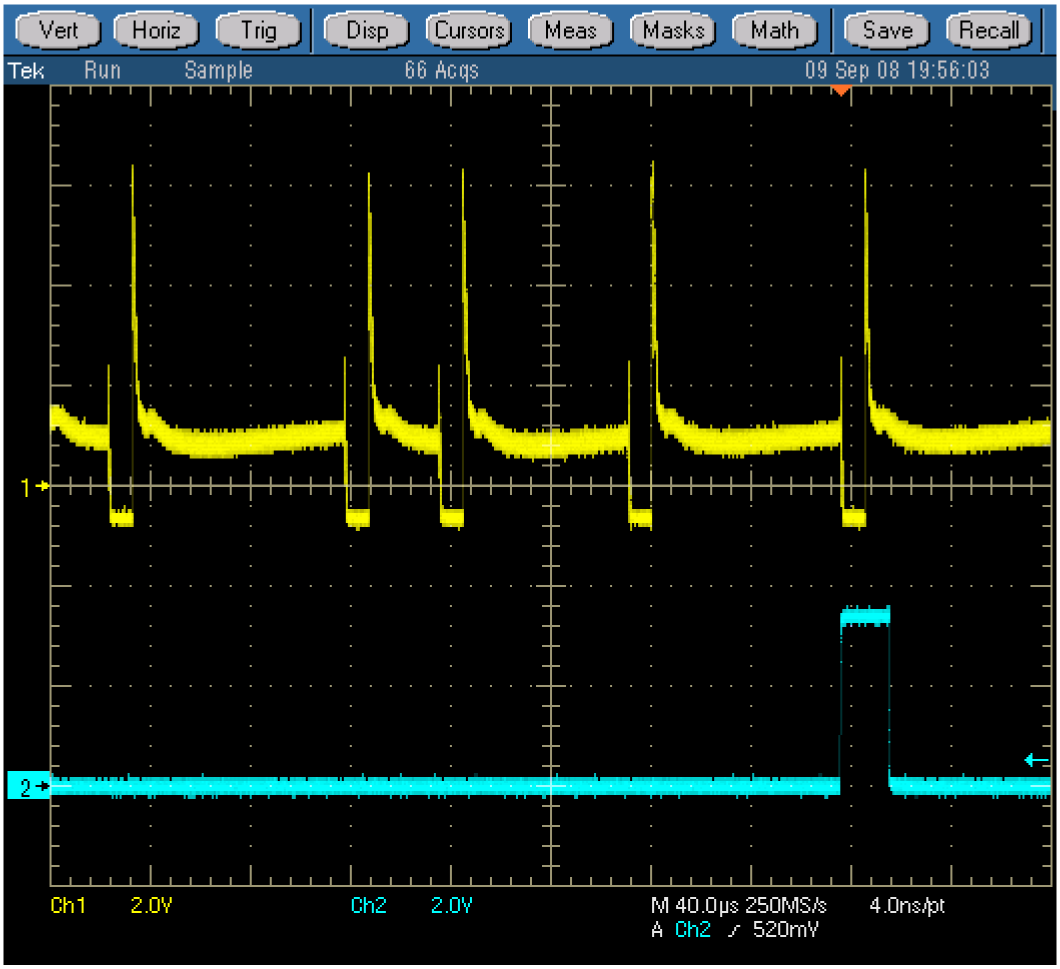
Receiver Inputs (No Tag 2 of 2)



Receiver Inputs (Tag 2 of 2)

4.3.4) AM Detector (Rx inputs configured for sub-carrier input) (continued)

The following picture is to show a detail of the pulse integrity at the reader's receiver input (top trace). This is an example of pulse rise / fall time and RF noise at the reader's receiver inputs. The bottom trace is the reader's IRQ pin.

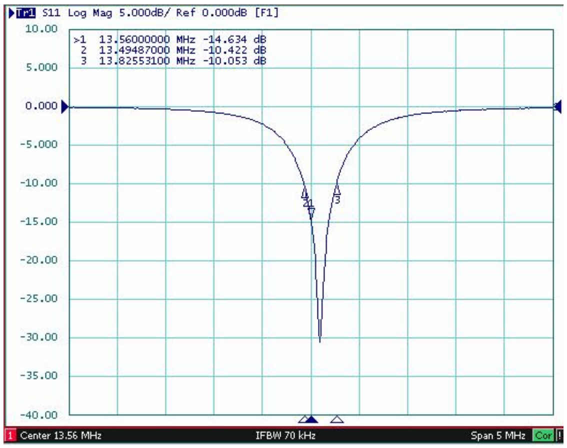


Receiver Input (Pulse Integrity)

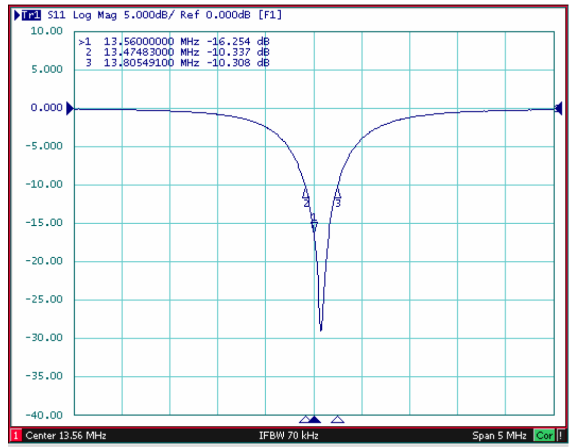
4.3) Antenna Plots

The antenna used in this application was 30 by 40 cm antenna (not shown), with a typical read range of 42 cm (16.5 inches) using a credit card size tag.

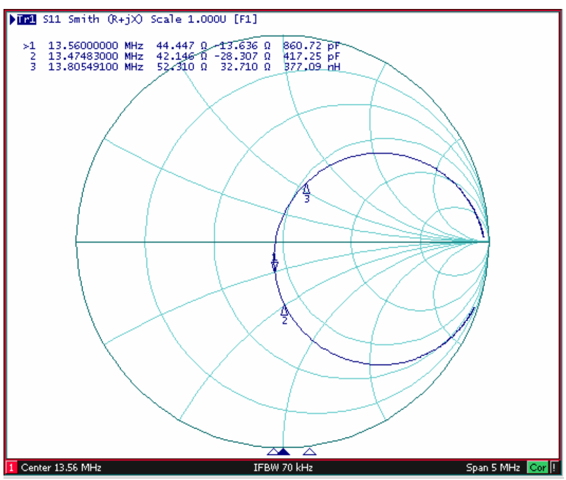
The antenna is tuned slightly off frequency in order to prevent transmitter power from saturating receiver inputs. The antenna circuit is adjusted off frequency as needed to yield a minimum 10 dB RL @ 13.56 MHz.



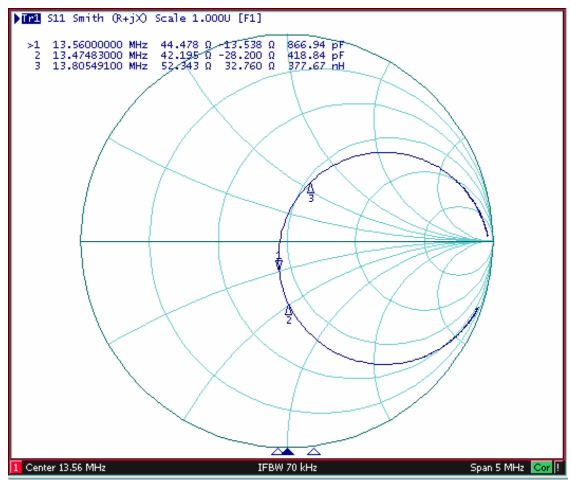
Ant #1 (RL = 14.6 dB)



Ant #2 (RL = 16.2 dB)

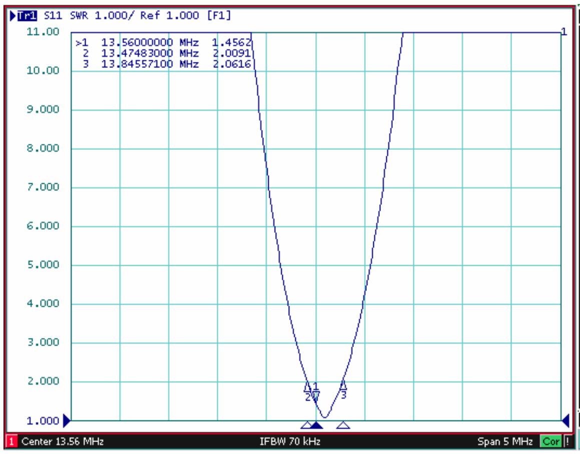


Ant #1 (Imp = 44.4 –j13.6)

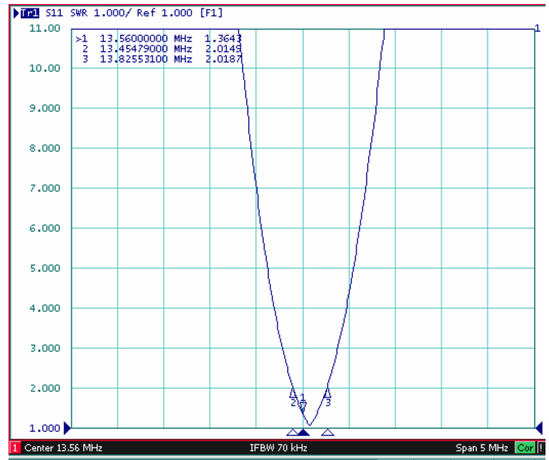


Ant #2 (Imp = 44.4 –j13.5)

4.3) Antenna Plots (continued)

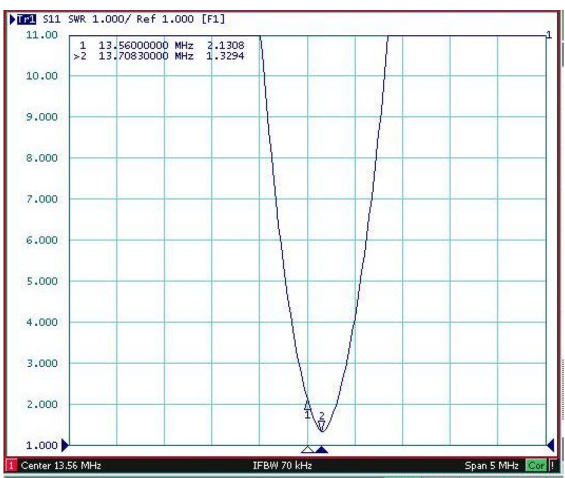


Ant #1 (VSWR = 1.45:1)

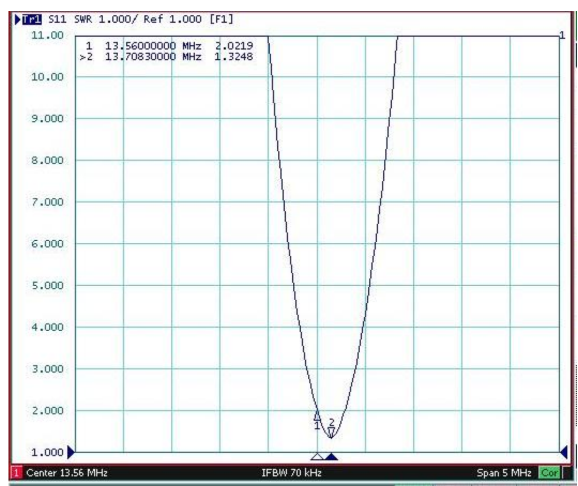


Ant #2 (VSWR = 1.36:1)

Note: Antennas #3, #4, & #5 are not tuned as previously shown in Ant #1 & #2. The difference being the manufacturer's failure to properly tune the antenna.

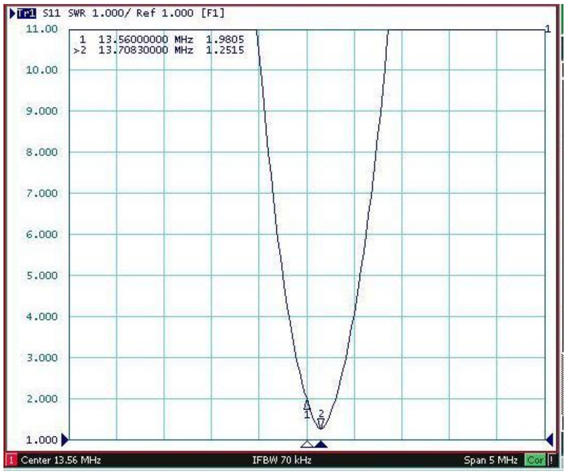


Ant #3 (VSWR = 2.13:1)



Ant #4 (VSWR = 2.02:1)

4.3) Antenna Plots (continued)



Ant #5 (VSWR = 1.98:1)

5.) HF Power Amplifier Test Measurements

Unit	Gate Drive Vp-p	Pwr Out (dBm)	+15 V DC @ ?? mA		Read Range		ISO15693 Check using 7.5 x 4.5 tag		
			R Load	Ant Load	inches	cm	Main RSSI	Aux RSSI	UID
0	7.20	+36	620 mA	485 mA	20.50	52	6	6	OK
1	6.88	+36	616 mA	464 mA	20.00	51	6	6	OK
2	7.84	+36	632 mA	486 mA	20.50	52	6	7	OK
3	7.00	+36	648 mA	489 mA	20.00	51	6	6	OK
4	7.50	+36	622 mA	470 mA	19.75	50	6	6	OK
5	7.48	+36	640 mA	482 mA	19.75	50	6	6	OK

Table 5.1
Test Measurements at 4 Watts (+36 dBm)

Unit	Gate Drive Vp-p	Pwr Out (dBm)	+15 V DC @ ?? mA		Read Range		ISO15693 Check using 7.5 x 4.5 tag		
			R Load	Ant Load	inches	cm	Main RSSI	Aux RSSI	UID
0	7.84	+30.1	396 mA	316 mA	16.25	41.5	6	6	OK
1	7.18	+30.3	392 mA	318 mA	17.00	43.0	6	5	OK
2	7.84	+30.3	398 mA	317 mA	17.00	43.0	5	6	OK
3	7.44	+30.6	423 mA	340 mA	16.50	42.0	6	5	OK
4	7.64	+30.3	389 mA	319 mA	16.50	42.0	6	5	OK
5	7.8	+30.5	415 mA	334 mA	16.25	41.5	6	5	OK

Table 5.2
Test Measurements at 1 Watts (+30 dBm)

6.) HF Power Amplifier Layout

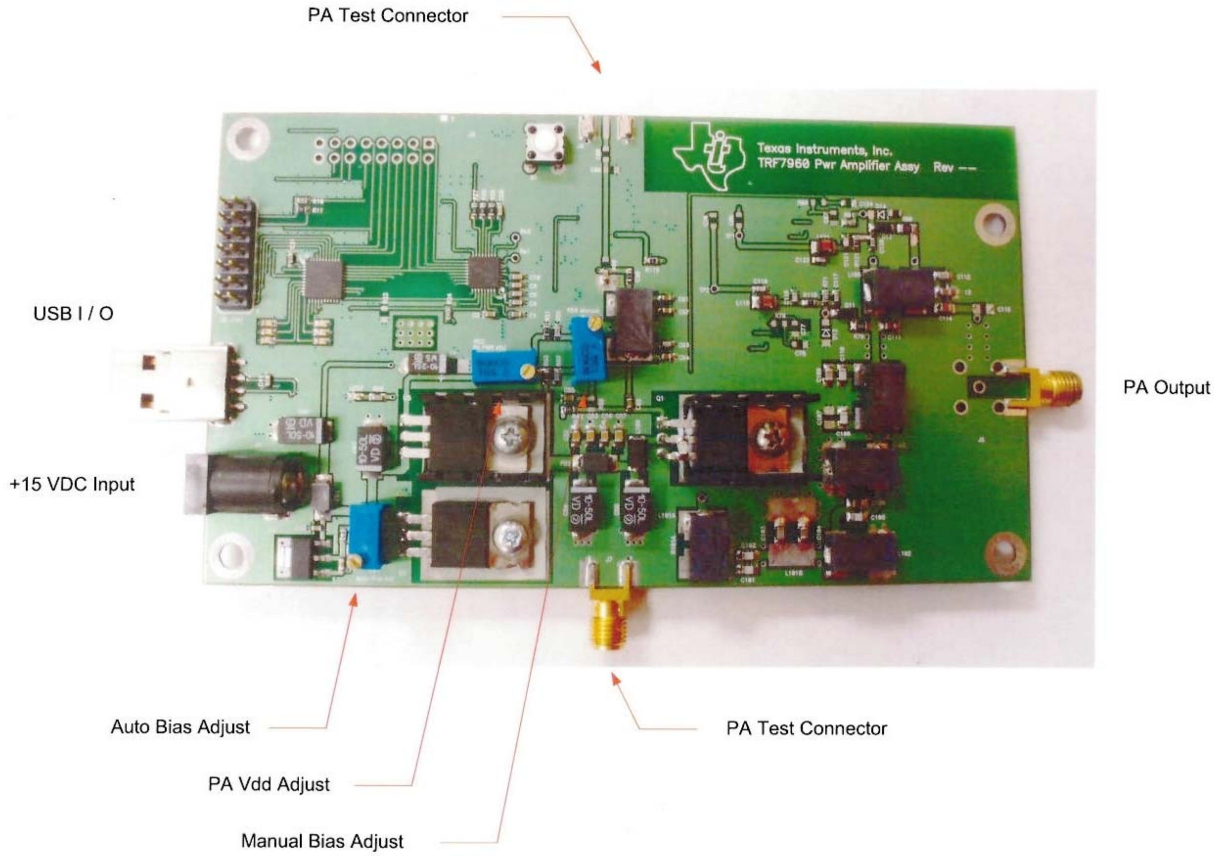


Figure 6
HF Power Amplifier Layout

The PA output power can be adjusted from 1 watt (+30 dBm) to 4 watts (+36 dBm) by setting the PA Vdd adjustment as needed. The Vdd adjustment range is 6 to 12.5 volts (typical).

.

A Manual Bias Adjust is provided as a secondary bias adjustment for bench / laboratory testing; typically set to 3.6 volts at the gate of Q1.

Auto Bias Adjust compensates the PA power output over temperature changes. The PA auto bias adjust is typically set for 3.6 volts at the gate of Q1.

PA test connectors are used for circuit development only. The PA output connector can be either SMA or TNC.

7.) List of Materials for HF Power Amplifier

9/16/2008 TRF796x RFID Reader EVM (13.56 MHz) Page 1 of 3

ITEM	QTY	REF DES	DESCRIPTION	Mfg	Mfg Part Number	Digi-Key P/N
1	Ref		Assembly Dwg, TRF7960 Pwr Amp (13.56 MHz) Rev --	Texas Inst		
2	Ref		Schematic, TRF7960 Pwr Amp (13.56 MHz) Rev --	Texas Inst		
3	Ref		Bd Outline Dwg, TRF7960 Pwr Amp (13.56 MHz) Rev --	Texas Inst		
4	Ref		Test Procedure, TRF7960 Pwr Amp (13.56 MHz) Rev --	Texas Inst		
5						
6	1		PCB FAB, TRF7960 Pwr Amp (13.56 MHz) Rev --	Texas Inst		
7						
8	1	J1	Connector, USB, (Type A), PCB R/A (Male)	Conec	33UBARS1-04PN1	www.conec.com
9	1	J2	Header (JTAG), 2x7 PIN, (0.100 inch STR), RoHS	Molex	10-89-7142	WM26814-ND
10	1	J3	Connector, Straight Ribbon	3M	30316-6002HB	30316-6002HB-ND
11	1	J4	Connector, DC Pwr (16VDC @ 5A)	CUI, Inc	PJ-058AH	CP-058AH-ND
12	1	J5	Connector, SMA (0.062 Edge Mount)	Johnson	142-0711-821	J629-ND
13	DNP	J6, J7	Connector, SMA (0.062 Edge Mount)	Johnson	142-0711-821	J629-ND
14	DNP	J5-Alt	Connector, TNC R/A PCB Female	Amphenol	31-5660	Mouser 523-31-5660
15						
16	1	S1	Switch, Reset, 1P1T, (20mA)	Panasonic	EVQ-PAC04M	P8006S-ND
17						
18	REF	Y1 (50 ppm)	Xtal, 13.56 MHz, (Xtal Load Cap = 18pF), (Ckt Caps = 27 pF)	Citizen	CS10 13.560MABJ-UT	Mouser 695-CS10-135
19			(50 ppm), (-10 to +60 deg C), (Package = 2 leads SMD)			
20						
21	1	Y1 (20 ppm)	Xtal, 13.56 MHz, (Xtal Load Cap = 18pF), (Ckt Caps = 27 pF)	Abracon Corp	ABM3-13.560MHz-B2-T	535-9101-1-ND
22			(20 ppm), (-20 to +70 deg C), (Package = 2 leads SMD)			
23						
24	4	C54, 58, 96, 97	Capacitor, 10uF, Tantalum, ±10% (50V) (Case E)	Vishay	293D106X9050E2TE3	718-1022-1-ND
25	1	C51	Capacitor, 10uF, Tantalum, ±10% (25V) (Case C)	Vishay	293D106X9025C2TE3	718-1050-1-ND
26	1	C61	Capacitor, 10uF, Tantalum, ±10% (10V) (Case A)	Vishay	293D106X9010A2TE3	718-1121-1-ND
27						
28	1	C40	Capacitor, 4.7uF, Tantalum, ±20% (10V)	Kemet	T491A475M010AS	399-1562-2-ND
29						
30	4	C50, 53, 57, 114	Capacitor, 0.1uF, ±10%, X7R, (100V), (0805)	Kemet	C0805C104K1RACTU	399-3486-1-ND
31	2	C52, C56	Capacitor, 0.01uF, ±10%, X7R, (100V), (0805)	Kemet	C0805C103K1RACTU	399-1159-1-ND
32						
33	1	C101	Capacitor, 560pF, ± 5%, NPO, (100V), (0805)	muRata	GRM2165C2A561JA01D	490-1612-1-ND
34	1	C102	Capacitor, 470pF, ± 5%, NPO, (100V), (0805)	muRata	GRM2165C2A471JA01D	490-1611-1-ND
35	4	C103, 105, 108, 110	Capacitor, 220pF, ± 5%, NPO, (100V), (0805)	muRata	GRM2165C2A221JA01D	490-1607-1-ND
36	1	C100	Capacitor, 100pF, ± 5%, NPO, (100V), (0805)	muRata	GRM2165C2A101JA01D	490-1599-1-ND
37	2	C111, 112	Capacitor, 68pF, ± 5%, NPO, (100V), (0805)	muRata	GRM2195C2A680JZ01D	490-1595-1-ND
38	1	C106	Capacitor, 47pF, ± 5%, NPO, (100V), (0805)	muRata	GRM2165C2A470JA01D	490-1593-1-ND
39	2	C104, 113	Capacitor, 27pF, ± 5%, NPO, (100V), (0805)	Venkel LTD	C0805COG101-270JNE	
40	1	C109	Capacitor, 12pF, ± 5%, NPO, (100V), (0805)	Venkel LTD	C0805COG101-120JNE	
41	DNP	C107, 115, 123	Capacitor, TBD, ± 5%, NPO, (100V), (0805)	muRata		
42						
43						
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45						
46	6	C3, 5, 7, 9, 25, 30	Capacitor, 2.2uF, ±10%, X5R, (10V), (0603)	Kemet	C0603C225K8PACTU	399-4911-2-ND
47						
48	1	C46	Capacitor, 1.0uF, ±10%, X5R, (16V), (0603)	Kemet	C0603C105K4PACTU	399-5090-1-ND
49						
50	8	C31, 41, 42, 45, 47,	Capacitor, 0.1uF, ±10%, X7R, (100V), (0603)	muRata	GRM188R72A104KA35D	490-3285-1-ND
51		55, 60, 95				
52						
53	8	C4, 6, 8, 10, 26	Capacitor, 0.01uF, (or 10nF), ±10%, X7R, (50V), (0603)	muRata	GRM188R71H103KA01D	490-1512-1-ND
54		33, 128, 129				
55						
56	REF		Capacitor, 2200pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H222JA01D	490-1459-1-ND
57						
58	4	C90, 91, 128, 228	Capacitor, 1000pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H102JA01D	490-1451-1-ND
59	1	C93	Capacitor, 560pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H561JA01D	490-1445-1-ND
60	1	C92	Capacitor, 470pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H471JA01D	490-1443-1-ND
61	2	C117, 120	Capacitor, 220pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H221JA01D	490-1435-1-ND
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80	QTY	REF DES	DESCRIPTION	Mfg	Mfg Part Number	Digi-Key P/N
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81						
82	4	C118,119, 121, 122	Capacitor, 100pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H101JA01D	490-1427-1-ND
83	2	C1, 2	Capacitor, 27pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H270JA01D	490-1413-1-ND
84	2	C74, 84	Capacitor, 10pF, ± 5%, NPO, (50V), (0603)	muRata	GRM1885C1H100JA01D	490-1403-1-ND
85						
86	DNP	C32, 88, 89,	Capacitor, TBD, ± 5%, NPO, (50V), (0603)	muRata		
87						
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91	1	R11	Resistor, 47K (0.1W), (0603)	Panasonic	ERJ-3GEYJ473V	P47KGTR-ND
92	4	R24, 30, 31, 50	Resistor, 10K (0.1W), (0603)	Panasonic	ERJ-3GEYJ103V	P10KGTR-ND
93	3	R25, 26, 27	Resistor, 1K (0.1W), (0603)	Panasonic	ERJ-3GEYJ102V	P1.0KGTR-ND
94						
95	6	R15,16, 17, 18, 19	Resistor, 560 ohms (0.1W), (0603)	Panasonic	ERJ-3GEYJ561V	P560GTR-ND
96		20				
97						
98	1	R51	Resistor, 390 ohms (0.1W), (0603)	Panasonic	ERJ-3GEYJ391V	P390GTR-ND
99	2	R55, 57,	Resistor, 220 ohms (0.1W), (0603)	Panasonic	ERJ-3GEYJ221V	P220GTR-ND
100	3	R10, 42, 53,	Resistor, 100 ohms (0.1W), (0603)	Panasonic	ERJ-3GEYJ101V	P100GTR-ND
101	2	R40,	Resistor, 10 ohms (0.1W), (0603)	Panasonic	ERJ-3GEYJ100V	P10GTR-ND
102						
103	2	R21, 62, 118, 121	Resistor, 0 ohms (0.1W), (0603)	Panasonic	ERJ-3GEYJ0R00V	P0.0GTR-ND
104						
105	2	R70, 80	Resistor, 0 ohms (0.25W), (0805)	Vishay	CRCW08050000Z0EA	541-0.0ATR-ND
106						
107	1	R100	Resistor, 0 ohms (0.25W), (1206)	Vishay	CRCW12060000Z0EA	541-0.0ETR-ND
110						
111	DNP	R23, 58, 90,	Resistor, TBD ohms (0.1W), (0603)			
112						
113						
114	1	R60	Resistor, 374 ohms (0.1W), (0603)	Panasonic	ERJ-3EKF3740V	P374HCT-ND
115	1	R61	Resistor, 121 ohms (0.1W), (0603)	Panasonic	ERJ-3EKF1210V	P121HCT-ND
116						
117						
118	2	R52, 56	Potentiometers, 500 ohms, Top Adj, 25 turn, 0.5 Watt	Bourns	3296Y-501LF	3296Y-501LF-ND
119	1	R41	Potentiometers, 50 ohms, Top Adj, 25 turn, 0.5Watt	Bourns	3296Y-500LF	3296Y-500LF-ND
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157						
158	**QTY**	**REF DES**	**DESCRIPTION**	**Mfg**	**Mfg Part Number**	**Digi-Key P/N**
159						
160	1	L100	Inductor, 1.0 uH, (Idc = 1.05 Amps), Un-shielded	API Delevan	P1812-102K	Mouser 807-P1812-102K
	4	L101, 102, 103, 10	Inductor, 538 nH, Q = 104, Test Freq = 50 MHz, Maxi Spring	Coilcraft	132-20SMJL	
	1	L105	Inductor, 422 nH, Q = 104, Test Freq = 50 MHz, Maxi Spring	Coilcraft	132-18SMJL	
	1	L90	Inductor, 169 nH, Q = 104, Test Freq = 50 MHz, Maxi Spring	Coilcraft	132-12SMJL	
	REF		Inductor Kit C319, Maxi Spring Air Core Inductors	Coilcraft	Kit C319	
	2	L118, 121	Inductor, 4.7uH, (Q = 31), (Idc = 400 mA)	Coilcraft	100LS-472XJLB	
	2	FB1, FB2	Ferrite Bead (42 ohms @ 10 MHz 10 Amps)	Steward	35F0121-0SR-10	240-2520-1-ND
	1	U1	CP2102, USB to UART, (-40 to +85 deg C), (28 pin QFN)	Silicon Labs	CP2102-GM	336-1160-ND
	1	U2	MSP430F2370, (-40 to +85 deg C), (40 pin QFN)	Texas Inst	MSP430F2370 IRHA	296-21750-1-ND
ITEM	1	U3	TRF7960, HF RFID Reader, (-40 to +110 deg C), (32 pin QFN)	Texas Inst	TRF7960 RHBT	296-20793-2-ND
	2	U4,U6	LM317DCY Adjustable Regulator (1.25 to 37 V @ 1.5 Amps)	Texas Inst	LM317DCY	296-23224-5-ND
	1	U5	LM1085IT-ADJ 3 Amp TO-220	National Semi	LM1085IT-ADJ	LM1085IT-ADJ-ND
161						
162	2	Q1, Q2	MOSFET, IRF510 PBF, 5.6 Amp, 100V, TO-220AB	Vishay IR	IRF510PBF	IRF510PBF-ND
163						
164						
165	2	Q1, U5	Heat Sink (TO-220) (Pwr Dis @ temp rise = 1.5W @ 40 deg C)	AAVID Thermalloy	577202B00000G	HS107-ND
	3	Q1, Q2, U5	Insulator, TO-220	AAVID Thermalloy	53-77-2G	Newark 24M0269
166	2	Q1, U5	Washer, #4 Nylon Shoulder Washer, 0.180 inch long	Keystone Electronics	3103	3103K-ND
167	1	Q2	Washer, #4 Nylon Shoulder Washer, 0.093 inch long	Keystone Electronics	3053	3053K-ND
168	3	Q1, Q2, U5	Nut, #4-40 W/Tooth Washer, Zinc-Plated, 1/8 inch thick	McMaster-CARR	90675A007	
169	2	Q1,U5	Screw, PPH #4-40 X 0.375 or 3/8 long, Zinc-Plated	McMaster-CARR	90272A108	
170	1	Q2	Screw, PPH #4-40 X 0.3125 or 5/16 long, Zinc-Plated	McMaster-CARR	90272A107	
171	AR	Q1, Q2, U5	Thermo Compound	TBD		
172						
173	2	D11, 13	Diode, 1N4148W, 100V, SOT-123	MCC	1N4148W-TP	1N4148WTPMSCT-ND
174	REF		Diode Schottky, SOT-23	STMicroelectonics	BAT46**Z**FILM	497-5559-1-ND
175						
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179	2	LED1 (PWR)	LED: water clear lense - Green (565nm), (2.1V @ 10mA)	LiteOn	LTST-C190GKT	160-1183-2-ND
180		LED7 (PA PWR)				
181						
182	1	LED2 (14443A)	LED: water clear lense - Red-Org (630nm), (2.0V @ 10mA)	LiteOn	LTST-C190EKT	160-1182-2-ND
183	1	LED3 (14443B)	LED: water clear lense - Yellow (585nm), (2.1V @ 10mA)	LiteOn	LTST-C190YKT	160-1184-2-ND
184	1	LED4 (15693)	LED: water clear lense - Red (660nm), (1.8V @ 10mA)	LiteOn	LTST-C190CKT	160-1181-2-ND
185	1	LED5 (Tag-It)	LED: water clear lense - Amber (610nm), (2.1V @ 10mA)	LiteOn	LTST-C190AKT	160-1180-2-ND
186	1	LED6 (Spare)	LED: water clear lense - Red-Org (630nm), (2.0V @ 10mA)	LiteOn	LTST-C190EKT	160-1182-2-ND
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190	TBD		Anti-Static Storage Bag (Zip Lock) (TBD inches)	3M		
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195			**AR == As Required**			
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197			**DNP == Do Not Place**			
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199			**Ref == Reference Information**			
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