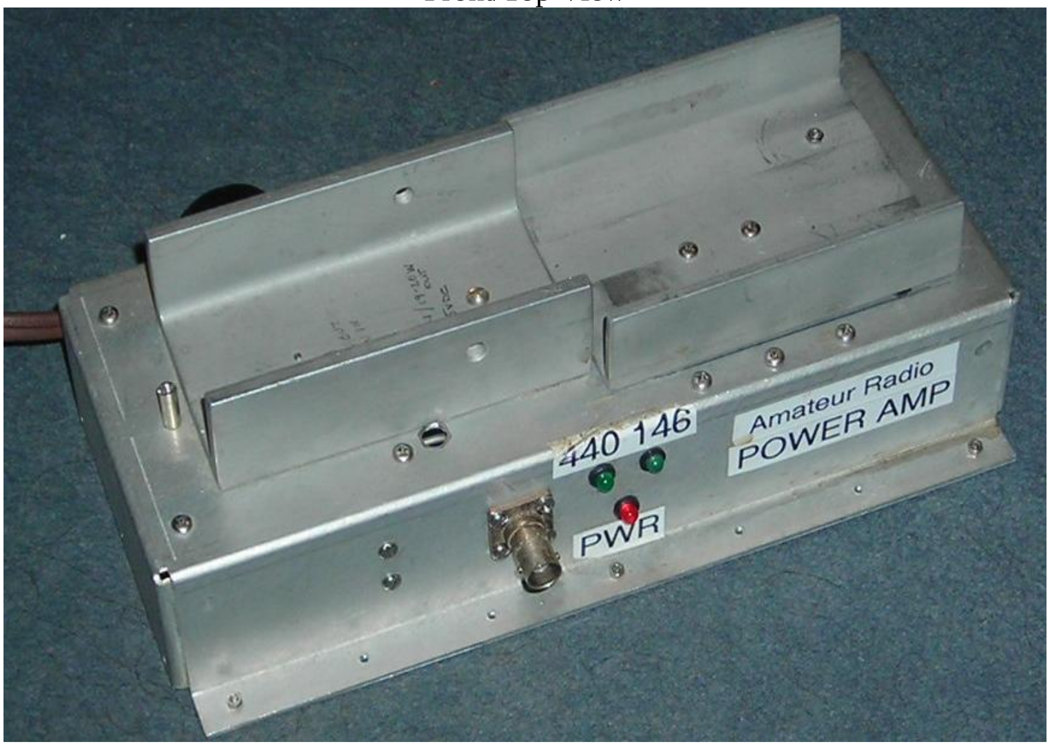
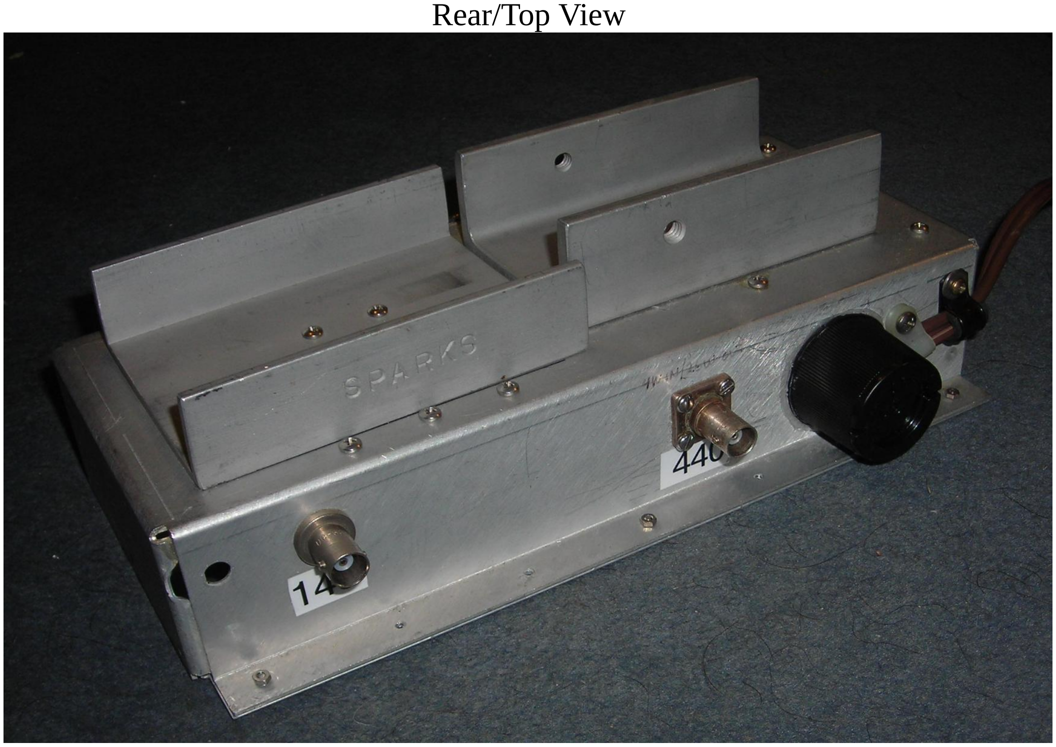
A DualBand Power Amplifier

Auto BandSwitching LDMOS Power Amplifier for the Amateur 2 M/70 cm Bands

Front/Top View



Rear/Top View



Circuit Description and other Musings:

It all started with a need to make my mobile FM setup more organized and less haywire. Ask anyone who seen my car. The end result is a neater solution with an auto band-switched unit that gives the amateur radio operator an indication of which band is being transmitted on. It allows for low-insertion loss on receive, and silent reliable T/R switching using PIN diodes. Based on some very good experiences I have had in the past with power MOSFETS [1] , I chose to stay with that device type. In this case, these are LDMOS devices that Woody, AK2F located for me [2]. These Mitsubishi units were not difficult to use, and the same can be said for several NXP and PolyFet devices I have used in past projects as well. The gain and power was as expected, and the data sheet information proved to be useful.

This document is meant to be self-explanatory, not a point by point construction article. It is intended for amateur radio use, not commercial or any other use. The amateur builder with some RF experience can see from the photos, schematics, parts lists and test data pretty much what to expect. If you are capable of UHF construction you already know all about short lead length, good grounds,etc. The low-inductance advantages of using several small-value ceramic chip capacitors in parallel verses one big chip cap,etc. Of course, any component substitution of any kind carries some risk, so be aware of this. It is suggested the reader reviews Tables 5,6 and 7 throughly.

Since this project uses LDMOS FETS, which can be static sensitive, it makes sense to use a ground wire to the Q1's gate. Attach (tack solder) a thin bare wire from Q1's mounting flange to the gate lead after removing it from the manufacturer's ESD packaging. Mount and install Q1 (with the wire) after all the other power amplifier components are mounted on the Power Amplifier PCB. With Q1 mounted in its PCB cutout, solder the gate and drain leads of Q1 onto the PCB. Then snip the bare wire.

This document being written January 2009 *hopefully* concludes this project which started in October 2004. The first item was the 70cm power amplifier with T/R switch and detector followed by Band-Detect circuit, diplexer and finally the 2M power amplifier with its T/R switch and detector. If the reader wonders why one would use "lumped components" at 70cm and "microstrip" at 2M for the power amplifier circuits, I will say "Because You Can!" For whatever reason, that's it's just the way the project evolved. Note that the 2M T/R switch is "lumped" while the 70cm T/R switch is "distributed" (coax). This Rev A addressed a problem of small capacitors at C6 and C8, which could fail due to high RF current in the drain circuit of the 2Meter PA.

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Internal Construction:

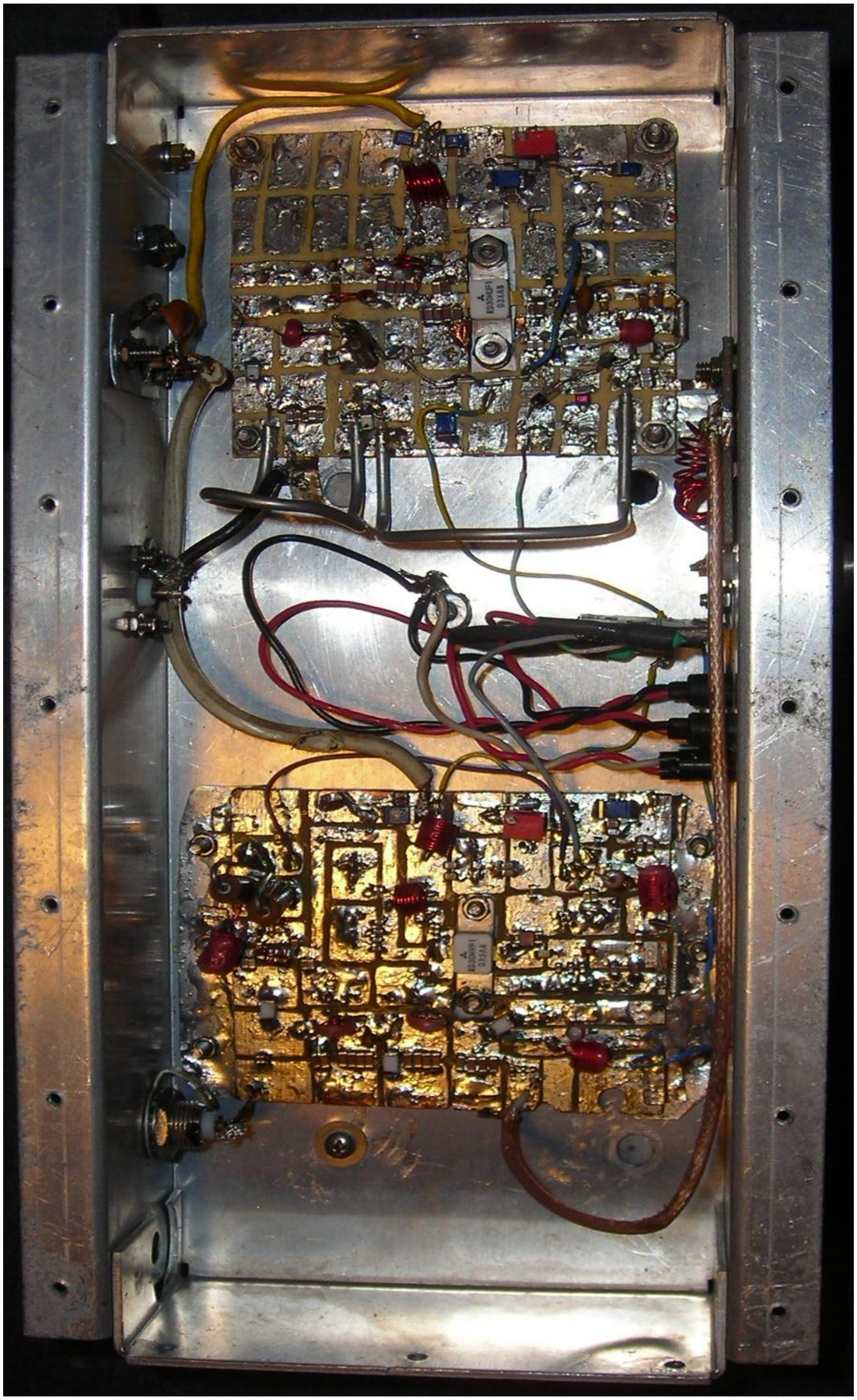


Fig 1. Block Diagram

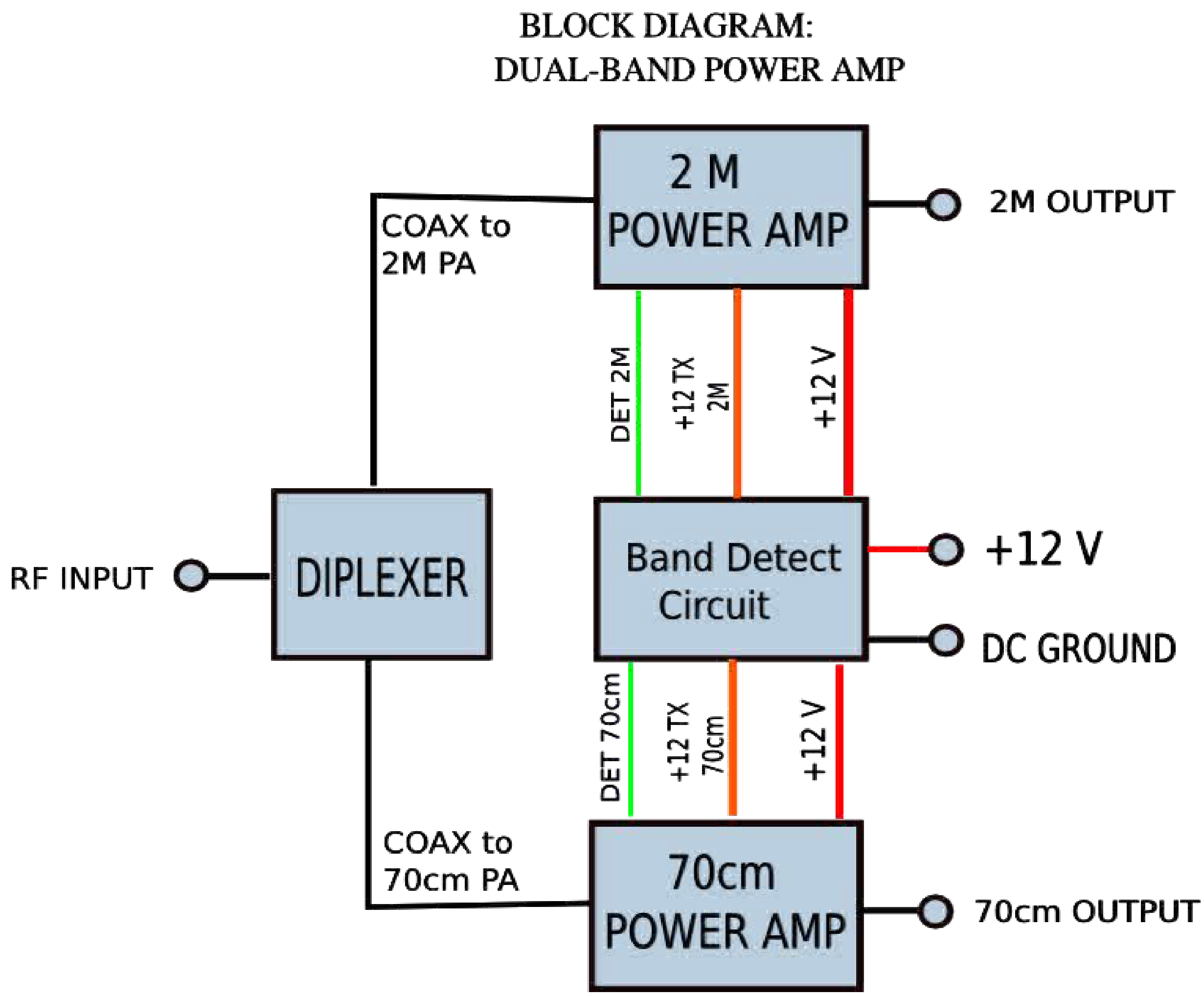


Figure 2. FrontEnd Diplexer

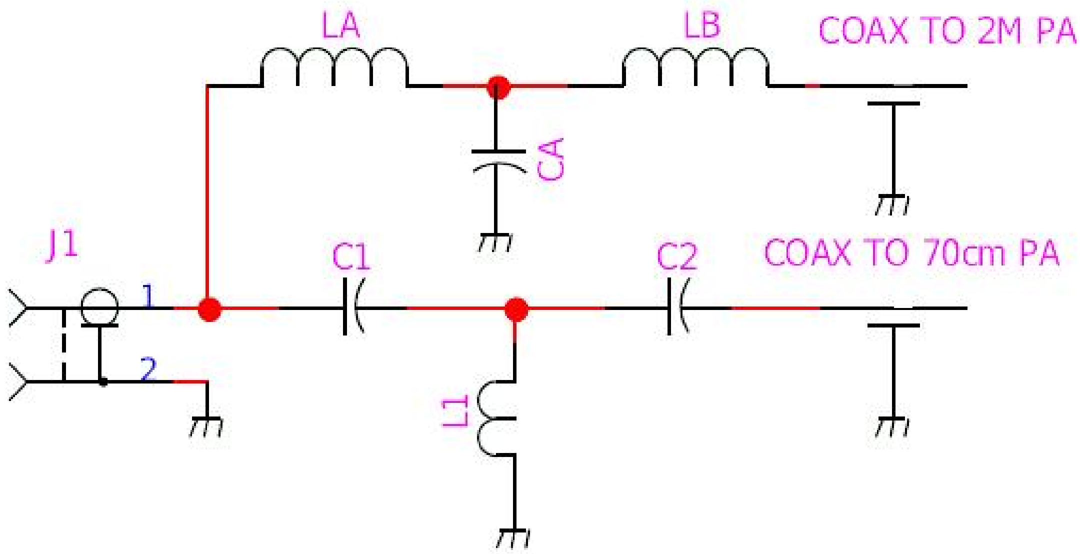


TABLE 1. FRONTEND DIPLEXER

REF DES	DESCRIPTION	NOTES
C1	CHIP CAPS ~4.2pF(1.5+2.7 pF) ,NP0	
C2	CHIP CAPS ~4.5pF (3.0+1.5pF),NP0	
CA	CHIP CAP 18pF NP0	
LA	COIL,~105nH, 5T,0.25"DIA,AWG#22	Leads~0.1" long
LB	COIL,~100nH, 5T,0.25"DIA,AWG#22	Leads~0.1" long
L1	COIL,~19.3nH, 2T,0.093"DIA,AWG#22	Leads~0.1" long
J1	BNC FEMALE BULKHEAD	

Figure 3. Band Detect Circuit

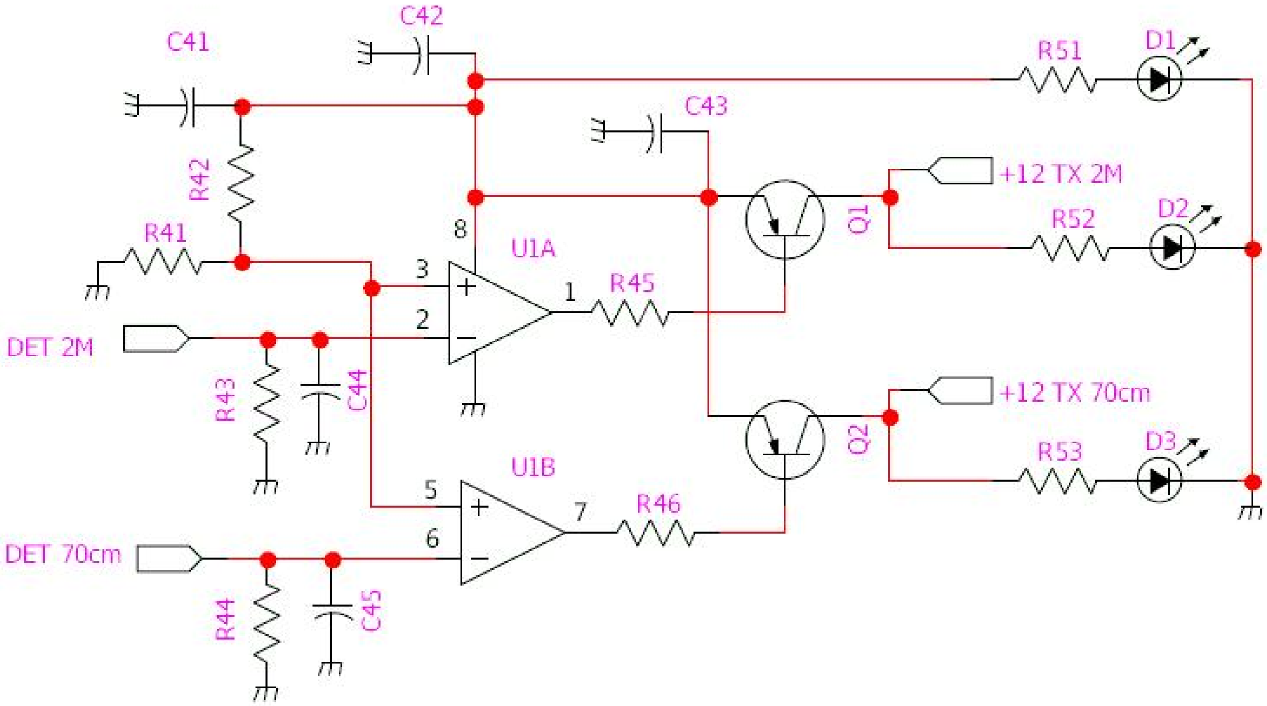


TABLE 2.BANDDETECT CIRCUIT

REF DES	DESCRIPTION	NOTES
C41,C42,C43	CHIP CAP 0.1uF 50V	
C44,C45	CHIP CAP 100pF NP0	
R41	CHIP RESISTORS ~570 OHMS (470+100 OHMS)	In -Series
R42	CHIP RESISTOR 82 K	
R43,R44	CHIP RESISTOR 100 K	
R45,R46	CHIP RESISTOR 1.5 K	
Q1,Q2	PNP TRANSISTOR,SOT-89, BCP53 or equiv.	
U1	LM393D	
R51,R52,R53	RESISTOR,	OFF-BOARD
D1	LED, GRN , (D1=POWER)	OFF-BOARD
D2,D3	LEDS, RED (D2=2M; D3=70cm)	OFF-BOARD

Figure 4.Schematic 2M Power Amp

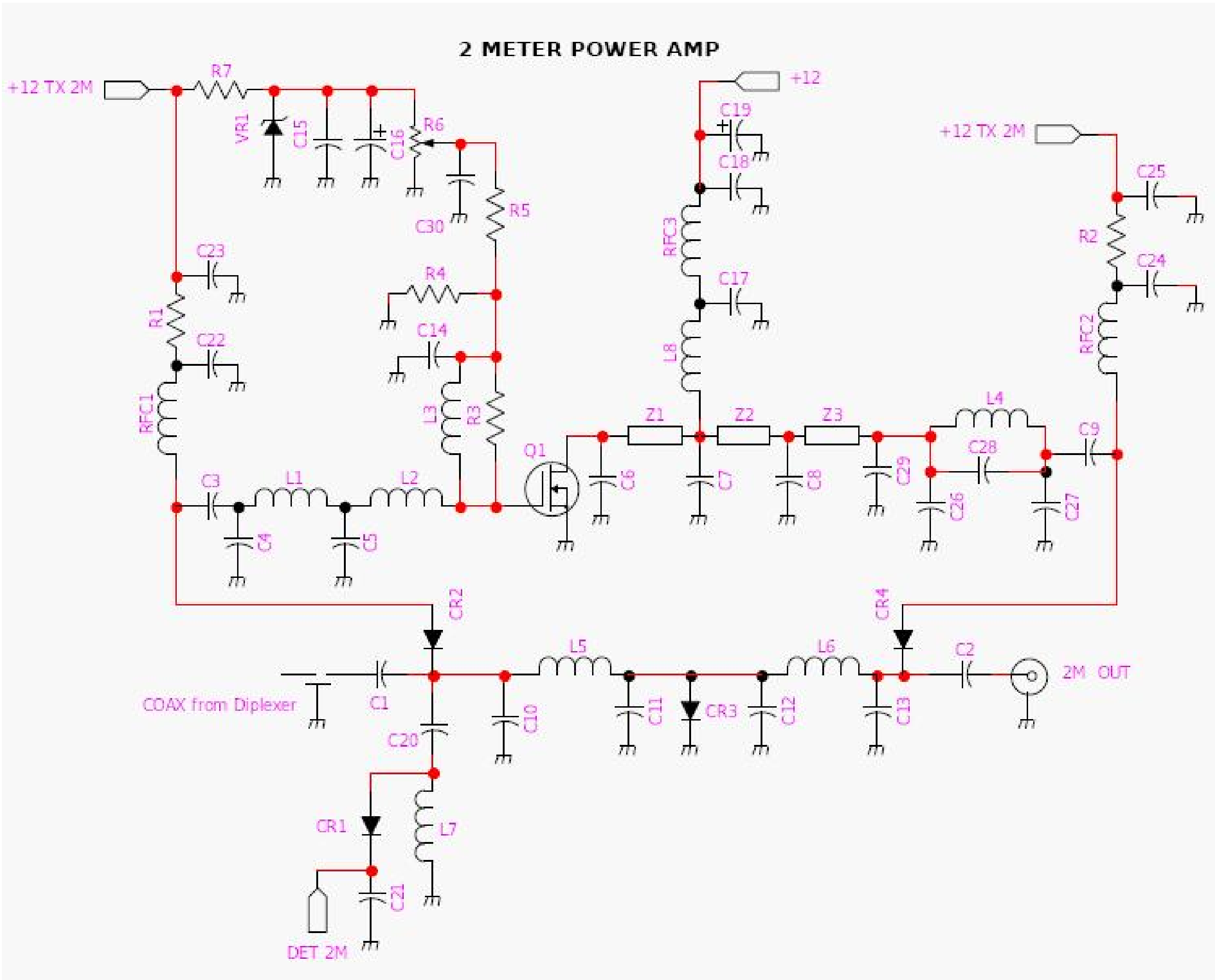


TABLE 3: PARTS LIST : 2 M POWER AMPLIFIER

REF DES	DESCRIPTION	NOTES
C1,C2	CHIP CAP 2200 pF 100V; 0805 SIZE	
C3,C26.C27	CHIP CAP 22 pF 50V	
C4	CHIP CAPS ~25 pF (22pF + 3 pF)	
C5,C29	CHIP CAPS ~66 pF (2 x 22pF)	
C6	CHIP CAPS ~66 pF (3 x 22 pF each),0805,1206 size	
C7	CHIP CAPS ~188 pF (4 x 47 pF)	
C8	CHIP CAPS ~80 pF (47 + 33 pF) 0805,1206 size	
C9	CHIP CAPS ~540 pF (2 x 270 pF)	
C10,C11,C12,C13	CHIP CAPS ~20pF (4 x 5 pF each)	
C14,C15,C17,C21,C22, C23,C24,C25,C30	CHIP CAP .01 uF 50V, 0603 or 0805 SIZE	
C16,C19	CHIP TANTALUM 10 uF; 25 WVDC	
C18	CHIP CAPS 0.2 uF (2 X .1 uF) 50 V	
C20	GIMMICK CAP ~1 pF	
C28	CHIP CAP 10 pF 100V	
CR1	Germanium Diode 1N34A	
CR2-CR4	PIN Diodes SM1001-M2 (Microsemi)	See also Aeroflex-Micrometrics
L1	CHIP IND 39 nH	Coilcraft
L2	CHIP IND 22 nH	Coilcraft
L3	CHIP IND 12 nH	Coilcraft
L4	COIL,Air-Core,~29nH;2T	Note
L5,L6	COIL,Air-Core, ~54nH;3T;AWG#28	Note
L7	COIL,Air-Core,~450nH;12T,AWG#28	Note
L8	COIL,Air-Core, ~200nH;7T	Note
RFC1,RFC2	CHOKE,Air-Core,~600nH;16T;AWG#28	Note
RFC3	CHOKE,Air-Core,~281nH;10T	Note
R1	330 OHMS, 1/2 W	
R2	75 OHMS 1 W (2 PCS,150 OHMS,1/2 W)	
R3	50 OHMS (2 PCS 100 OHM CHIP RES)	
R4	56 K CHIP RES	
R5	100 OHM CHIP RES	
R6	Multi-turn TRIMMER,10 K	
R7	CHIP RES, 1500 OHMS	
Q1	LDMOS TRANSISTOR, RD30HVF1	Mitsubishi
VR1	ZENER DIODE;5.1V,1N751A	
Z1	MICROSTRIP W= 100mils; L=500mils	
Z2	MICROSTRIP W= 100mils; L=400mils	
Z3	MICROSTRIP W= 100mils; L=2100mils	

Note : Unless otherwise noted :AWG#24 Enameled Copper Wire wound on 5/16" diameter drill.
Note 2: PCB is .062" THK FR4 (G-10), e~4.5

Figure 5. Schematic 70cm Power Amp

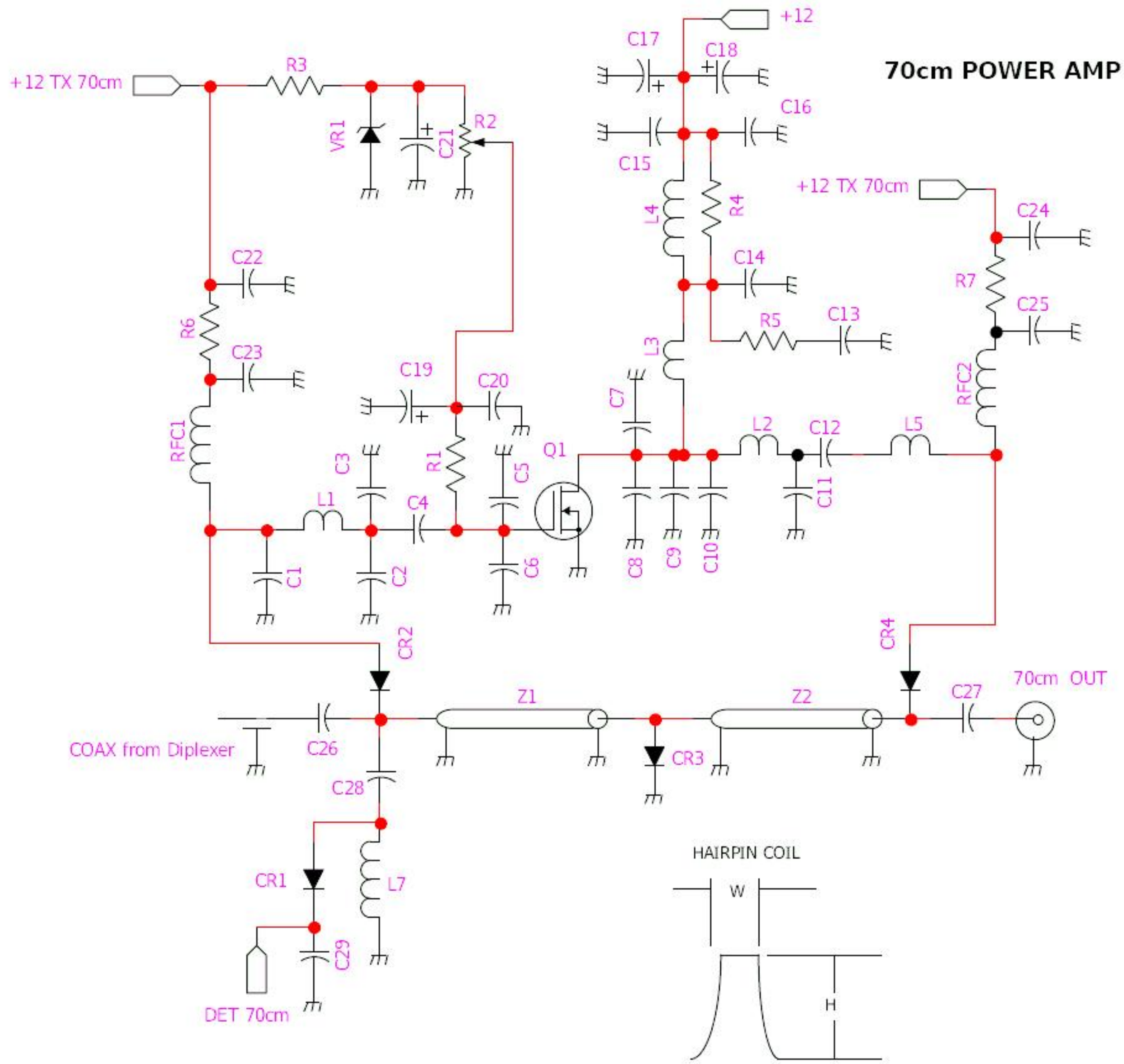


TABLE 4: PARTS LIST : 70cm POWER AMPLIFIER

REF DES	DESCRIPTION	NOTES
C1,C9,C11	CHIP CAP 5 pF 100V NP0	
C2,C5.C6,C8	CHIP CAPS ~10 pF (2 X 5pF each) 50V NP0	
C3	DISC OR CHIP CAP 12 pF NP0	
C4	CHIP CAPS ~94 pF (2 x 47pF) NP0	
C7	CHIP CAPS ~25 pF (5 x 5 pF) NP0	
C10	CHIP CAPS ~20 pF (4 x 5 pF) NP0	
C12,C14,C23,C25	CHIP CAPS ~200 pF (2 x100pF each) NP0	
C13,C15,C29	CHIP CAP 100pF NP0	
C16,C22,C24	CHIP CAP .1 uF 50V ,0603 or 0805 SIZE	
C17,C18,C19,C21	CHIP TANTALUM 1.5 uF; 25 WVDC	
C20	CHIP CAPS 0.02 uF (2 X .01 uF) 50 V	
C28	GIMMICK CAP ~0.5 pF	
CR1	Germanium Diode 1N34A	
CR2-CR4	PIN Diodes SM0502-M1 (Microsemi)	See also Aeroflex-Micrometrics
L1	1-TURN HAIRPIN; h=0.3",w=0.25"	see Fig 5
L2	1-TURN HAIRPIN; h=0.4",w=0.35"	see Fig 5
L3	COIL,Air-Core, ~20 nH;2T ;wind on 5/32" drill	Note
L4	COIL,Air-Core,~ 247 nH;6T ;wind on 9/32" drill	Note
L5	1-TURN HAIRPIN; h=0.2",w=0.2"	see Fig 5
L7	COIL,Air-Core;~372nH;12T,AWG#28;wind on 5/32"drill	Note
RFC1,RFC2	CHOKE,Air-Core;~114nH;6T;AWG#28;wind on 5/32"drill	Note
R1	390 OHMS, CHIP RES	
R2	Multi-turn TRIMMER,10 K	
R3	1.8 K CHIP RES	
R4	100 OHM CHIP RES	
R5	50 OHM CHIP RES	
R6	330 OHM, 1/2 W	
R7	75 OHM, 1 W	
Q1	LDMOS TRANSISTOR, RD30HUF1	Mitsubishi
VR1	ZENER DIODE;5.1V,1N751A	
Z1,Z2	SEMI-RIGID COAX CABLE, 0.085"DIA, 4.9" LONG	

Note :Unless otherwise noted: AWG#24 Enameled Copper Wire wound on 5/16" diameter drill.
Note 2: PCB is .062" THK FR4 (G-10), e~4.5

APPENDIX A. SUGGESTED PROCEDURE

When taking on a project of this magnitude, it helps to break it down into manageable portions. The following sequence of construction/test proved helpful.
(Still, this is *not* intended to be a construction article!)

TABLE 5: SUGGESTED PROCEDURE

1	Power Amps Assembly (omit and bypass T/R Switch/detector circuit).
2	Test/Tune each Power Amp. Set each gate bias potentiometer for 0V initially. Adjust it gradually during tuning process . Apply +12 Volts and +12 V TX (2M or 70cm) manually to each. RF input power of approx 2 watts was used. With +12 V and +12V TX (2M or 70cm) manually applied and NO RF power input, the quiescent drain current should be similar to values in "Measured Data" table. Once you adjust the Quiescent Drain Current for the
3	Build T/R Switch and Detector circuits on each power amplifier board.
4	Test Power Amps with T/R switch and detector circuits. Apply +12 V TX to the T/R switches to enable TX. Test the detector circuits for DC output with RF applied. Detectors should work over the range of ~200mW to 4 watts input (positive output).
5	Build/Test Front-end Diplexer. A spectrum analyzer with RF generator or a network analyzer is recommended.
6	Build and test Band Detect Circuit. Do a simple DC test for this assembly. Power the Band Detect circuit with +12 V. With 0 Volts (grounded DET 2M or grounded DET 70cm inputs there should be no +12 V TX 2M or +12 V TX 70cm drive. Apply ~90 mV DC to these inputs and the +12 V TX 2M or +12 V TX 70cm drive should be available. The corresponding LED's should light up. The threshold is ~82mV.
7	Final Assembly: Interconnect Front-End Diplexer,Band Detect Circuit,2M Power Amp and 70cm Power Amp. The interconnect signal names should be consistent from one assembly to another. Check your wiring!
8	Final Test: Power up with +12 VDC. This should be able to detect the RF input for each respective band (from~200mW to ~4 watts) and you should get close to the original power output that you saw in step 4. You should see the LED's light only when you apply RF input- if otherwise, check for instabilities.

APPENDIX B. SOME TEST DATA

TABLE 6: Measured Values:(For Reference Only)

PARAMETER	2M DATA	70cm DATA	Notes
Quiescent Drain Current: Only +12 applied. NO +12 V TX or RF input!	~1.1 microamp	~11 microamp	A very low drain current with no drive is a good indication. Not for potentiometer adjustment!
Quiescent Drain Current: +12 and +12 V TX (2M or 70cm) applied. NO RF input!	56 mA	228 mA	Your values may vary. This mode "Class C" does not require much quiescent drain current. Once you set the Quiescent Drain Current, do not adjust the potentiometer again. Do not adjust by gate voltage.
RF Power Input (Measured From HT using Diode Detector and 10 dB Pad)	LP= 0.365W HP=4.08 W	LP=0.33 W HP=3.12 W	ICOM IC-T7H
RF Power Output (Bird Model 4304)	LP= 18W HP= 33 W	LP= 6W HP= 25W	Measured in Mobile Installation, Engine Idling
Calculated Gain	LP~ 16.9 dB HP~ 9.1dB	LP~ 12.6dB HP~ 9.0 dB	For Reference Only! Your results may vary.
Harmonics	~-60 dBc	~-60 dBc	(HP 8558B/182T)

TABLE 7: RX PATH

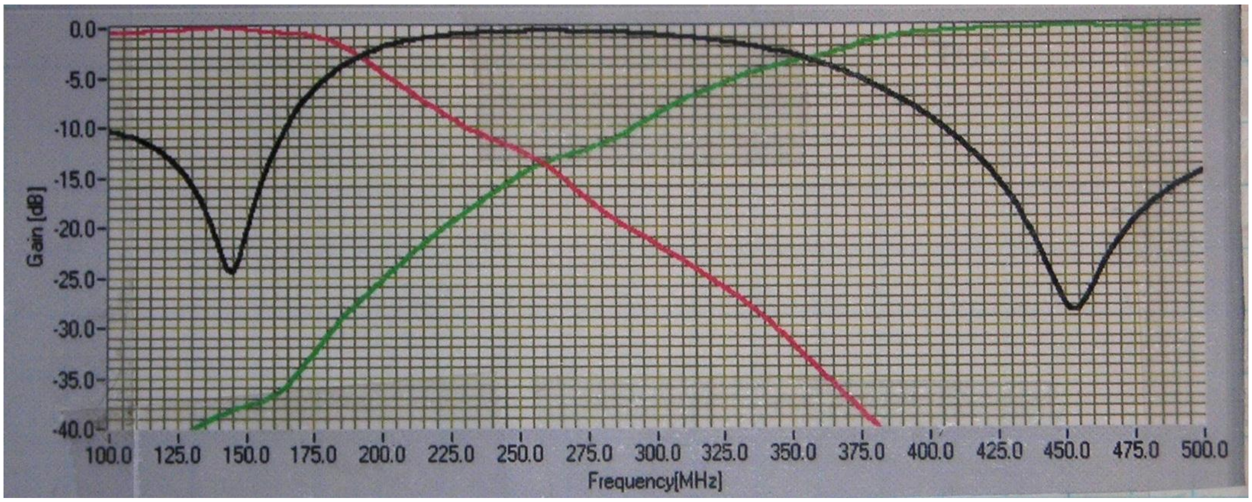
RX Path Data	RX Path Loss
2M to Input Port	0.61 dB @ 2M
70cm to Input Port	1.1dB @ 70cm

Notes:

[1] Three Fine Mice, QST,December 1986.pg 19
[2] Diamond Advanced Components, 450Washington St, Dedham,MA 02026
Also, Woody AK2F encouraged the author to document this project.

APPENDIX B. SOME TEST DATA (CONTINUED)

SWEPT DIPLEXER RESPONSE:
The Red trace is dB[S21] for common port (J1) to the "Coax to 2M PA" line.
Likewise, the Green trace is db[S21] for common port (J1) to the "Coax to 70cm PA" line.
The Black line is return loss for J1.



Some spot frequency values: (Your results may vary. These are exceptional!!)

BAND	db[S11]	db[S21]	db[S31]	db[S22]	db[S33]
2M	23.8	0.14	38.2	22	
70cm	25.4	51.9	0.19		32