200W 136 kHz transmitter

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1. Introduction

My first transmission experiments on 136 kHz band where based on a little TX build around surplus components, particularly the output transformer was wound on a TV EAT transformer. In Italy is impossible to find Philips 3C85 cores.
For 200W transmitter I decided a more professional approach: buy a surplus switching power supply core and design the output transformer according to ARRL Handbook suggestions.
The success was assured at the first try, so I publish my experience for all people interested in this band.

2. Design requirements

- Power supply: my biggest transformer was 200 W 30 V, coming from an old HI-FI amplifier
- Output transformer core: coming from flea market, light blue colour, marked as A-438281-2-9H9-3, OD = 47 mm, ID = 24 mm, height = 13 mm. No information about μ.
- Output impedance: variable, about 50 ohm.
- Configuration: class D single mosfet
- Mosfet to be used: coming from flea market, with the following characteristics. It's an obsolete (no data sheet could be retrieved) and cheap (1 euro) device and is similar to the well-known IRFP450.

  - V_{DSS} = 500 V max
  - I_D = 10 A max
  - P_D = 200 W max
  - $R_{DS(on)}$ = 0,35 ohm (about)

3. Design steps

3.1. Measuring the toroid permeability

Wind the toroid with some turns; use any kind of insulated wire, according with the **table 1** and measure the inductance with a suitable instrument.
Then using the TOROID program (TNX G4FGQ, R. J. Edwards), input the mechanical dimensions, try some permeability values ad find the μ value that give a computed inductance close to the measured one (if you are a perfectionist do some form of regression). In my case a μ = 180 resulted in the values reported in the third line of the **table 1**.

Table 1

Number of turns (N)	10	15	20	25	30	35
Measured inductance (L, μH)	31	67	115	175	247	351
Computed inductance, given a μ=180 (L, μH)	28,3	63,7	113	177	255	347

3.2. Dimensioning the output stage

Starting with my power supply characteristics I compiled the **table 2** with five hypotheses based on my power supply transformer.

Table 2

Hypothesis	1	2	3	4	5
Vdc (V)	35	35	32	30	33
Idc (A)	4	5	6	6	5
Pin (W)	140	175	192	180	175
Pout (W)	112	140	153	144	132
Zout (ohm)	5,5	4,4	3,3	3,1	4,1
X_L (ohm) (= 6 x Zout)	33	26,4	20	18,6	24,6
L (μH) @ 136 kHz	38,6	31	23,4	21,8	28,8

Pout was computed estimating an efficiency of 80%.
Zout was computed using the ARRL handbook simplified formula:

$$Zout = Vdc^2 / 2Pout \quad (1)$$

The complete formula should consider the voltage drop on the mosfet:

$$Zout = (Vdc – V_{DS(on)})^2 / 2Pout \quad (2)$$

If you are designing a push-pull stage you can apply the following formula: (TNX G0MRF, David Bowman)

$$Zout\ (drain\ to\ drain) = 2\ (Vdc – V_{DS(on)})^2 / Pout \quad (2bis)$$

The ARRL handbook suggests that RF non-resonant transformer must have an inductive reactance (X_L) at least 4 times the impedance. I decided to use $X_{L=}$ 6 times the impedance.

On the basis of the preceding experience I decided for the column 5 hypothesis, so for primary winding:

Z = 4.1 ohm and L = 28.8 μH

From **table 1** the primary winding must have 10 turns (28,3 μH).
The secondary winding should match the antenna impedance, in my case about 50 ohms. **Table 3** report the secondary winding turns, computed with the following formula:

$$(Npri/Nsec)^2 = Zpri/Zsec \quad (3)$$

Table 3					
Number of turns	15	20	25	30	35
Z secondary (ohm)	9,2	16,4	25,6	37	50

3.3. Measures on the running prototype

The transmitter was connected to the antenna and, starting from the first tap on the transformer (15 turns) I searched what tap was better (maximum antenna current for Idc < 6A). If you have a dummy load you can do a better test. In my case 30 turns tap resulted in the following table measured values:

- Vdc = 32 V
- Idc = 5.8 A
- Pin = 186 W
- Pout = 150 W (for an efficiency of 80%)
- Zout = 3.3 ohm (see formula 1)
- Npri = 10 turns
- Nsec= 30 turns (the better tap)
- Iant = 1.7 A (measured antenna current)
- Computed antenna resistance ($Pout / Iant^2$) = 52 ohm
- Measured antenna resistance = 50 ohm (about one month later)

The transformer turn ratio (10 / 30) confirms the impedance matching from the 3.3 ohm of the output stage to the 50 ohm of the antenna system (see formula 3).
The running equipment seems closer to the column 3 of the **table 2** hypotheses.

4. Circuit description

The TX was built on an unetched printed circuit board, a very good earth plane, using the dead bug technique.

The TX must be excited with a double frequency (272 kHz); this is better for the following motivations:

- The exciter is good also for a coming soon push-pull transmitter
- The flip-flop give a symmetrical square wave output
- During receiving time the flip-flop is unpowered, so no 136 kHz signal is injected into the receiver.

The input stage can handle a 5 to 12 V pp signal (TTL or CMOS, probably, but not tested, also sinusoidal signals). My Xtal oscillator uses an ex CB Xtal 27.xxx MHz divided by 100.
The TC4426 must have very short wires bypass capacitors, soldered to the ground plane.
The BD136 transistor on a little heat sink handles the CW (or QRSS) manipulation. The circuit come from well-known 136 kHz transmitters.
The capacitor C15 between the TC4426 and the mosfet gate protect the mosfet from destruction in the case of carrier absence.
The mosfet is mounted on a heat sink coming from an old Pentium 2 CPU, with the little fan running at 12 V. Another fan in the box keeps the temperature of the transmitter comfortable; the source pin go to the ground plane directly.
The by-pass capacitors C2 e C3 must be of the best quality you can find, rated to 4 times Vdc, I use two 1 μF and one 2,2 μF polyester 250 volt in parallel. Don't use electrolytic capacitors and keep the terminals as short as possible.
The primary winding of T1 is 1 mm^2 Teflon insulated wire, the secondary 1 mm^2 enamelled wire.

The Z1 varistor, in my case, is not mounted: no mosfet explosions at this time!
The low pass output filter is copied from other lowfers projects.

5. Possible variations

It's possible to design the output stage for other power supply. Following are the maximum suggested limits for the mosfet employed:

- Vdc 90 volt max
- Idc 6 – 7 ampere max
- Pin 250 watt

For lower voltages and higher currents consider a bigger heat sink.

6. References

This project was possible thanks the very good job done by other lowfers and published on the WEB.

http://www.alg.demon.co.uk/radio/136/home.htm Steve Rawlings, GW4ALG
http://www.picks.force9.co.uk Dave Pick, G3YXM
http://www.g0mrf.freeserve.co.uk David Bowman, G0MRF

Components		
C1	10µF 35V	Electrolytic
C2	2.2µF 250V	Polyester
C3	2.2µF 250V	Polyester
C4	0.1µF	Ceramic
C5	2.2nF 1000V	Polyester
C6	10nF 1000V	Polyester
C7	0.47µF	Ceramic
C8	47µF 35V	Electrolytic
C9	4.7nF 1000V	Polyester
C10	3.3nF 1000V	Ceramic
C11	22nF 1000V	Polyester
C12	10nF 1000V	Polyester
C13	2.2nF 1000V	Polyester
C14	4.7µF 35V	Electrolytic
C15	0.47µF 250V	Polyester
C16	10µF 35V	Electrolytic
C17	47000µF 70V	Electrolytic
D1	1N4004	
D2	MBR150	Schottky 150V
D3	25 A 200 V	Bridge
F1	6.3 A	
J1		Key connector
J2		VFO connector
J3		ANTENNA connector
J4		RX antenna connector
K1	SPDT Relay, 12V	
L1	54uH	Amidon T200-2, 64 turn 1 mm diam. enamelled
L2	54uH	Amidon T200-2, 64 turn 1 mm diam. enamelled
Q1	BD136	With heat sink
Q2	2SK1029	With heat sink and fan
R1	2.2k	
R2	3.9k	
R3	150ohms 2W	
R4	33k	
R5	100k	
R6	680ohms	
R7	10ohms 2W	
R8	4.7k	
R9	10k	
R10	100k	
R11	10ohms	
T1		See text

T2	2 x 30V 200W	Power supply transformer
U1a	TC4426	
U1b	TC4426	Not used, ground input
U2a	4013	Not used, ground inputs
U2b	4013	
Z1	270Veff	MOV or Varistor, not mounted