Ramsey AM-25 Efficiency Enhancement (Revised Oct. 31, 2012)

Increasing the field strength of a radiated signal will, in general, increase the usable range of the signal. The range will increase approximately as the square root of the output power. Since the DC input to a transmitter is limited to 100 mW under the Part 15 rules (15.219) increasing the power out is not simply a matter of increasing the power in. Another approach is to improve the efficiency of the final stage so the output power is increased without exceeding the 100 mW input power limit. Changes to the Ramsey AM-25 are described here which resulted in more than double the original circuit efficiency and which thereby doubles the power output while maintaining compliance with Part 15.219.

For the data reported below, two dummy load resistances were used. One, a 50 ohm resistor, represents the standard load which most transmitters are designed to feed and which facilitates comparison with other devices. The other, a 29 ohm resistor, represents a practical resistive load which can be expected when a base coil loaded Part 15.219 compliant antenna system is used.

It was determined by measurement that the original efficiency was 29% driving the 50 ohm load and was 23% driving the 29 ohm load. After modification the efficiencies were 63% and 53% respectively indicating more than double the efficiency after the modification.

This report describes each modification and the resulting efficiency For compliant operation R29 must be shorted to lower the DC power adjustment range. The results are reported in the order that each modification was developed but it is likely, though it was not tested, that each modification can be done independent of the others (with the exception of replacing R3 where the circuit became unstable with the MTP3055). This will allow an increase in efficiency without the necessity of requiring all modifications be done at once.

For all the efficiency numbers reported, the DC power input to the final amplifier was set as close as was convenient to 100 mW by adjusting VDD via R23 and a fixed operating frequency of 1670 kHz was used. A constant 13.8 VDC was present at the DC power input. The following data are presented as a testing guide for those who may want to implement these modifications:

VDD = the DC voltage measured at the junction of R34 and R5 to ground (the bias test point from the Ramsey Manual)
VDS = the DC voltage measured from drain to source of the output MOSFET.
ID = the DC current calculated as ID = (VDD-VDS)/(R33+R34).
PIN = the DC power calculated as PIN = VDSxID.
RL = the dummy load resistance.
Vout = the RMS AC voltage measured across RL.
Pout = the AC power delivered to the load calculated as Vout^2/RL
Eff = the efficiency calculated as Pout/PIN x100%.

The instrumentation used was a Fluke 8000A DMM for RL, VDD, VDS, R33, and R34.
A Fluke 123C Scopemeter was used for Vout.

There are some advisories for those who may perform these modifications. These were tested only at the operating frequency stated and though improved efficiency should result at other nearby frequencies this was not confirmed. The higher efficiency means changes to the RF load will change the input power more than previously and the final operating condition of PIN <= 100 mW will need to be adjusted with the antenna system connected. The audio potentiometer setting should be set after the power is set for proper modulation.

The second and higher harmonic content at the output was estimated using a LTspice simulation of the final circuit with the FFT function and RL = 29 ohms. The simulated second harmonic was down 26.5 dBc with higher harmonics down more than 49 dBc. An on air check with a communications grade receiver revealed no associated identifiable signal at the second, third, fourth, and fifth harmonic frequencies suggesting that the harmonics were down more than predicted by the simulation.

The modifications and associated data are presented here:

Original Efficiency: 22.6 and 28.5% (29 and 50 ohm loads respectively)
RL=29 Ohms, VDD=3.43V, VDS=0.75V, ID=134mA, PIN=100.5mW, Pout=22.8mW, Eff=22.6%
RL=50 Ohms, VDD=3.38V, VDS=0.79V, ID=129.5mA, PIN=102.3mW, Pout=29.1mW, Eff=28.5%

Mod 1: Efficiency 27.3 and 32.5%

Remove L4 and replace with a 51 uH inductor between the R33/C18 junction and C1 where previously connected to L4. A surplus inductor was used in the prototype but L4 can be reconnected such that the drain of Q3 connects to the L4/C1 junction. The inductance value is not critical but should be greater than 30 uH. It appears that the intent of the original design was to drive a high impedance load such as a length of wire, thus the impedance step up transformer. It is not needed for loads below 65 ohms. If used with a length of wire as an antenna this and the following modifications are most likely not useful.

RL=29 ohms, VDD=3.60V, VDS=2.91V, ID=34.5mA, PIN=100.4mW, Pout=27.4mW, Eff=27.3%
RL=50 ohms, VDD=3.60V, VDS=2.93V, ID=33.5mA, PIN= 98.2mW, Pout=31.9mW, Eff=32.5%

Mod 2: Efficiency 46.0 and 52.7%

Replace the seven pole output filter by removing L1, L2, L3, C2, C3, C4, C5, C6, and C7 with a 5 pole filter with L1=L2=11.3uH (27 turns #28 wire on T44-15 core), C2=C5=1000pF, C4=1600pF, and L3= a jumper strap. The existing L1 and L2 can be rewound as specified and used here. This change results in the largest increase in efficiency but it may not work well for frequencies appreciably different from 1670 kHz.

RL=29 Ohms, VDD=3.40V, VDS=2.64V, ID=38.0mA, PIN=100.3mW, Pout=46.2mW, Eff=46.0%
RL=50 Ohms, VDD=3.66V, VDS=3.00V, ID=33.0mA, PIN=99;0mW, Pout=52.2mW, Eff=52.7%

Revised Mar 7 2011
The original report recommended replacing the MTP3055 with a 2N6660 FET. It was later determined that the voltage on the gate of the 2N6660 was very near the absolute maximum rating for the device. Testing with a 2N3904 BJT yielded better efficiency without the high voltage problem. Therefore the following modification has been changed to include this new information and the previous Mod 3 and Mod 4 have been deleted.

Mod 3: Efficiency 53.4 and 73.1%

Remove and replace Q3 with a 2N3904 BJT. Mechanically, the 2N3904 can be mounted using the PC board holes originally used for the 3055. There is no need for a heat sink when operating at a PIN of 100 mW. Confirm that the base, collector, and emitter leads are connected properly. The base connects to the gate pad, the collector to the drain pad, and the emitter to the source pad.

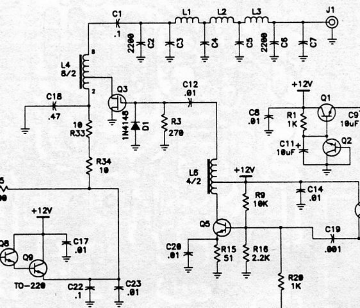
Remove R3 and replace with a 1 K resistor. This is optional but the circuit was tested with R3=1k.

RL=29 ohms, VCE=1.99V, IC=51.0mA, PIN=101.5mW, Pout=54.2mW, Eff=53.4%
RL=50 ohms, VCE=2.32V, IC=43.0mA, PIN= 99.8mW, Pout=73.0mW, Eff=73.1%

Revised Oct. 31, 2012
Mod 4: Efficiency 81.9%

Replace L1 and L2 with 50 turns #28 on T50-2 core. Use type CG0 caps for C3, C4, and C5.

RL=29 ohms, VCE=2.77V, IC=35.4mA, PIN=98.0mW,Pout= 80.3mW, Eff=81.9%



C1
.1
L1
L2
L3
J1
2200
C2
C3
C4
C5
2200
C6
C7
L4
8/2
8
2
Q3
C12
.01
+12V
Q1
C18
.47
1N4148
D1
R3
270
C8
.01
R1
1K
C9
10uF
C11
10uF
Q2
10
R33
R34
10
L6
4/2
+12V
R9
10K
C14
.01
+12V
Q5
C19
.001
Q8
C17
.01
C20
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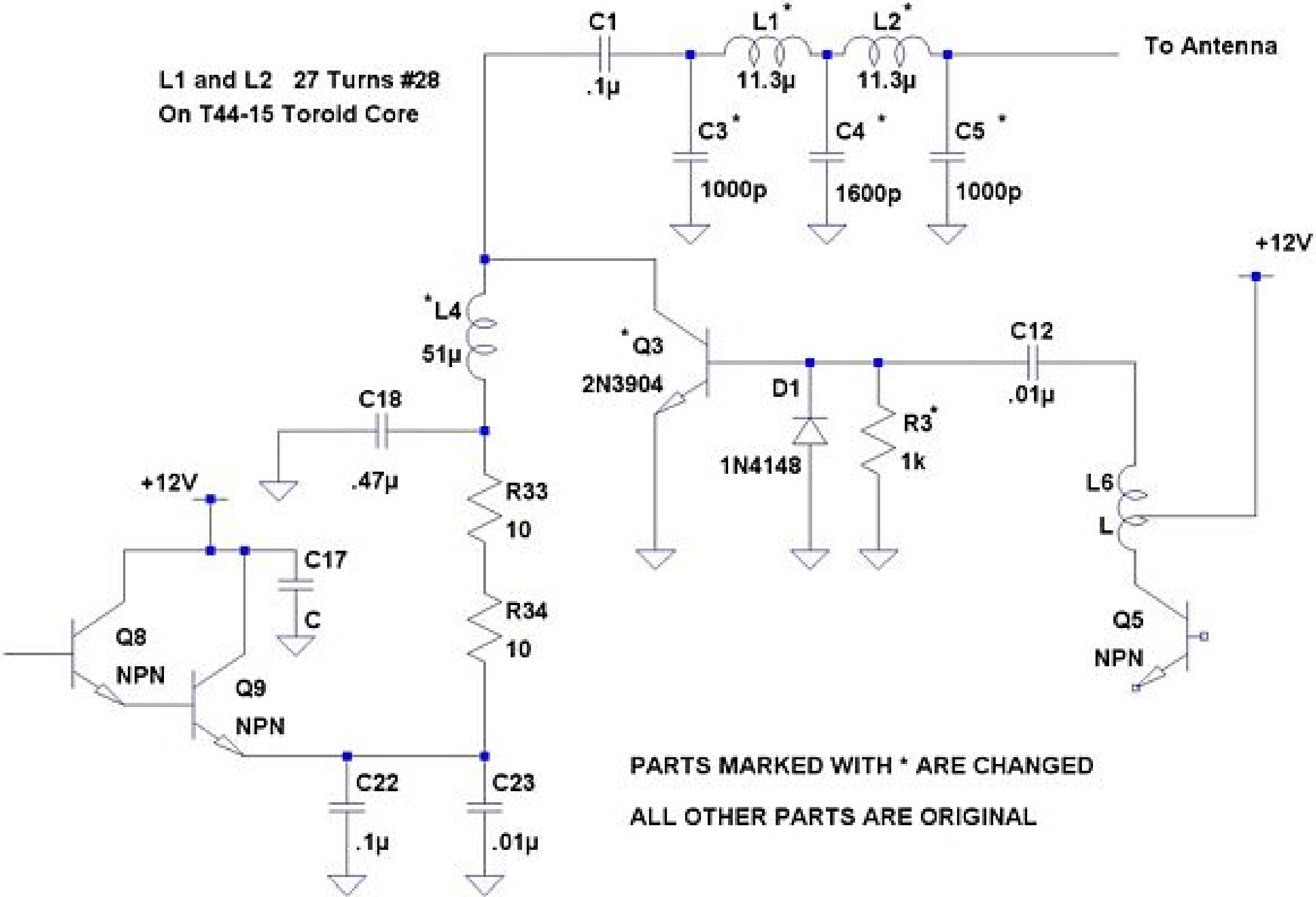
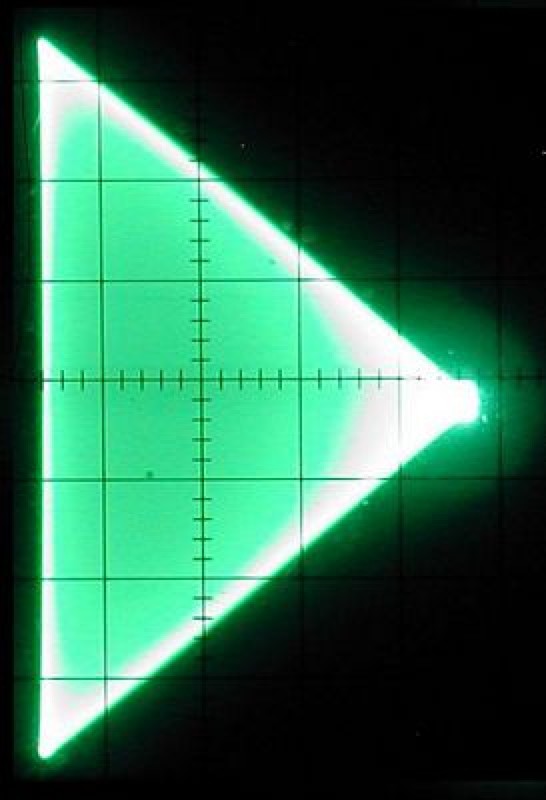
R15
51
R16
2.2K
Q9
TO-220
R20
1K
C22
.1
C23
.01

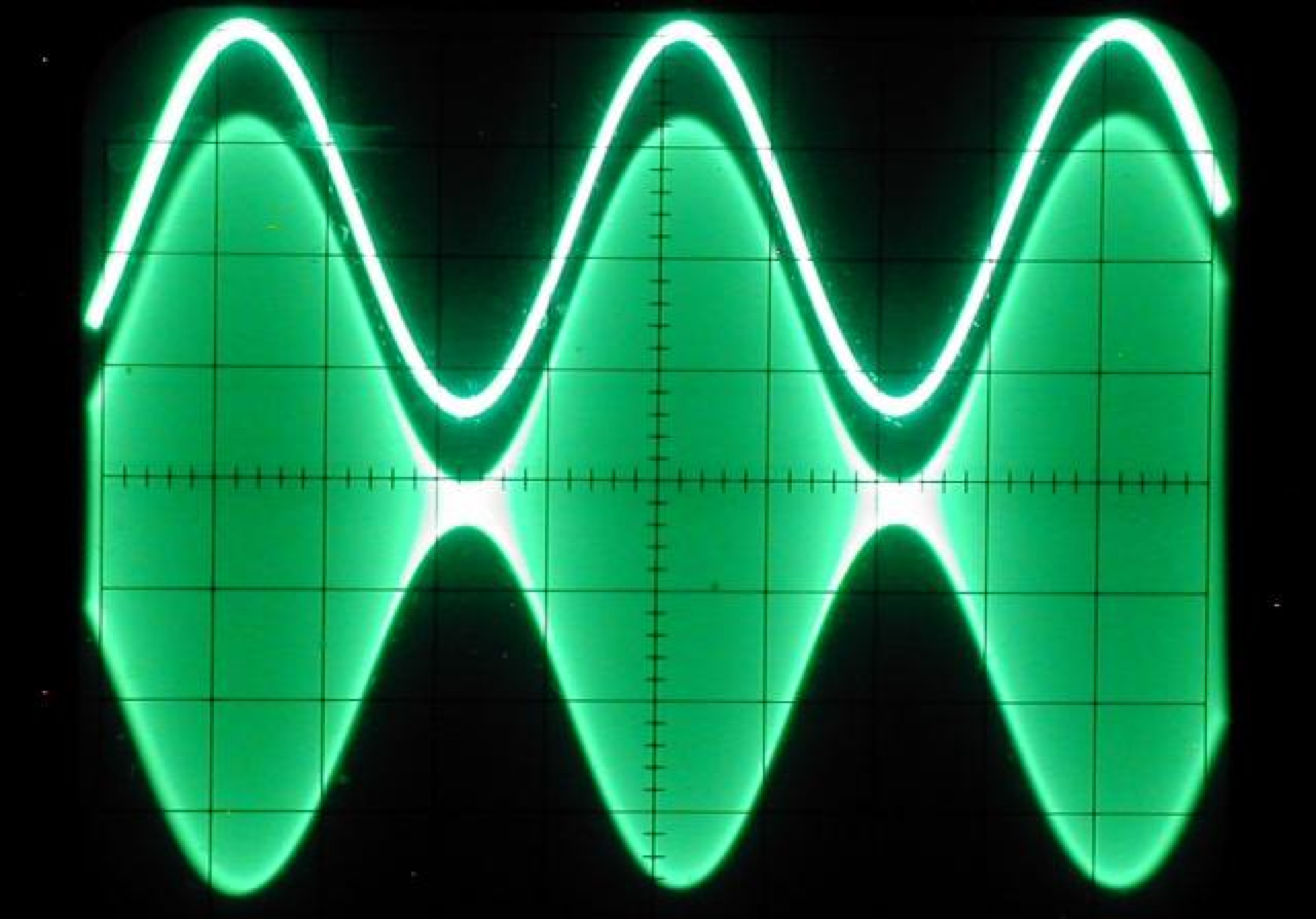


PARTS MARKED WITH * ARE CHANGED

ALL OTHER PARTS ARE ORIGINAL

MODIFIED AM-25 OUTPUT STAGE Rev 1



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