91. Class E Amplifier for UST-40 Speaker **DRAFT 1.1**

UFO Doctor, April 18th, 2015, rev. May 22th, 2015

1. Introduction

The Class E Amplifier, invented by Nathan Sokal in 1975, is a tricky RF-circuit and cannot explained here in detail. Please look at the many references in Google to this topic!

In short, a LC-circuit is loaded and short-circuited by a FET at 50% Duty Cycle. The efficiency is near 90%, if low-loss inductors and the appropriate nFET for a distinct frequency are selected!

2. Simulations

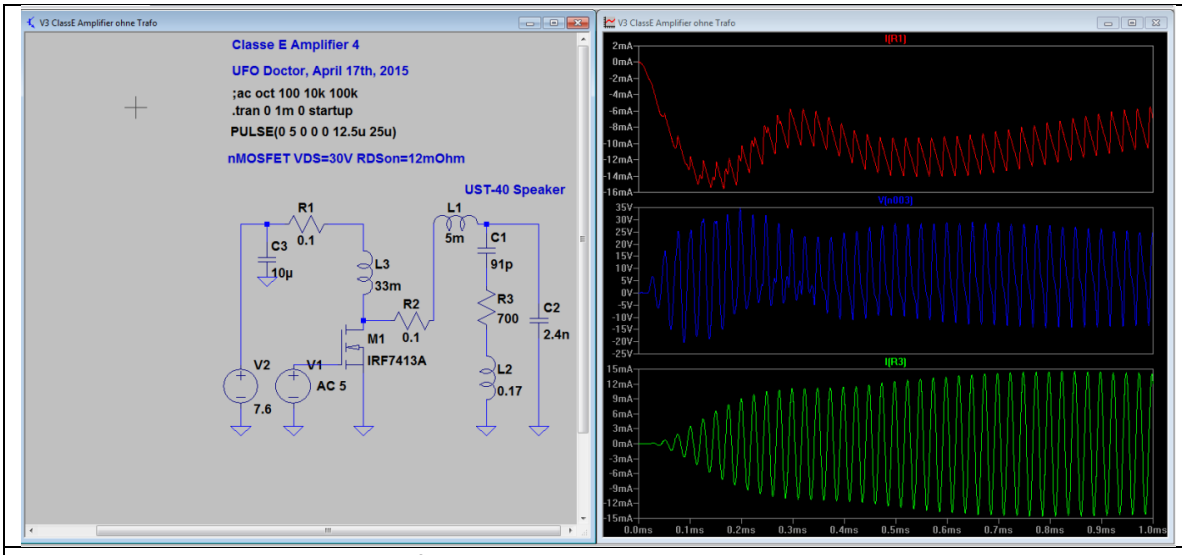

Fig. 1: Transient Analysis, Value of L1 IS VERY CRITICAL!
Only 10mA Input Current, Output about 35Vpp,WARNINGS: Start-up needs about 0.5msec!

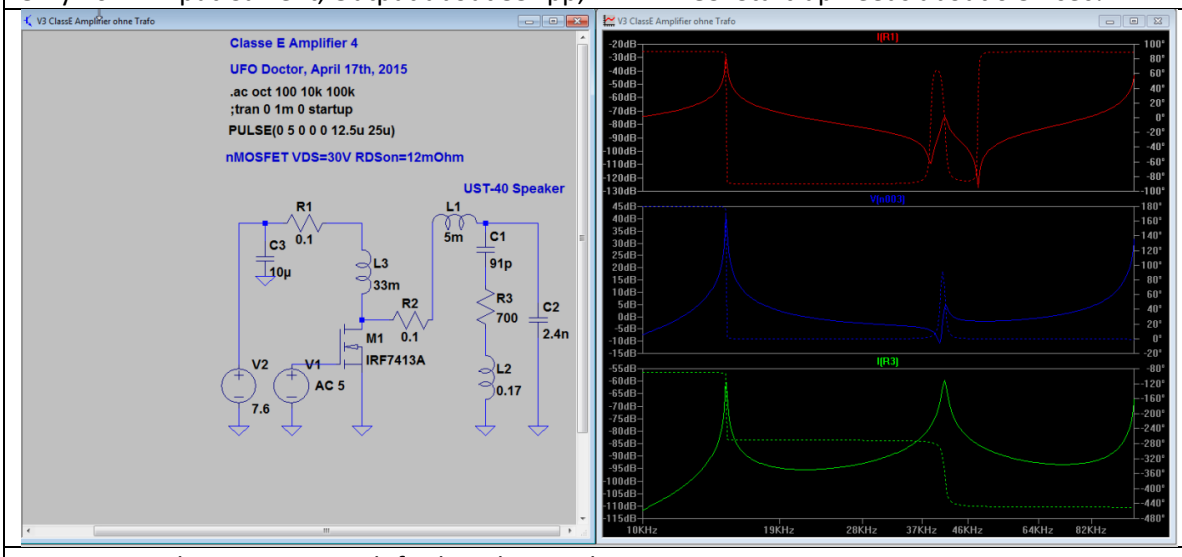

Fig.2: AC-Analysis, Resonanc shifted to about 41kHz

Internal circuit of the US speaker UST 40 see: http://www.midnightscience.com/ultrasonics.html

3. Inductors:

(In general: Self-resonance > operation frequency, low loss)

Type	L mH	RDC Ohm	Comment
Distrelec 33 12 88	33	130	Not good for this job
Ferrite Epcos	6.8	12	Ok for this job!

4. Experiments

4.1. Preliminary Experiment

Supply 7.4V, 1 Ohm Shunt in GND line for supply current monitoring

nMOSFET	L3 mH	L1 mH	Average DC mA	Out Vpp
BSH1052.215	6.8	6.8	16	89

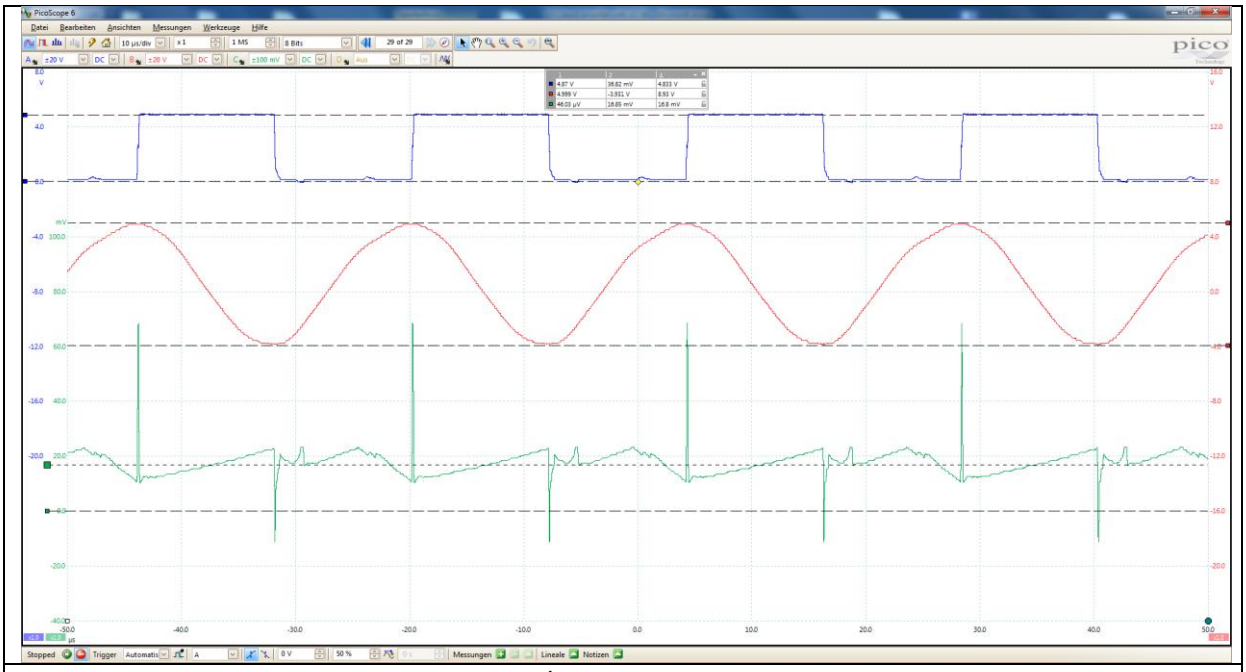

Fig.3: Experimental Data, Time Scale 20usec/Div, LP 5MHz, Maximum at 41.6kHz
Top A: Gate, +/-20V, 4.9V
Middle B: Voltage at UST+/-20V, **Probe 10x1**, 89Vpp
Bottom C: Voltage at 1Ohm Shunt in GND Line, +/-100mV, 16mV=16mA

Comment:

- The maximum amplitude appears not at 40kHz, but at about 41.5kHz. Please ask me not why!

4. 2 Experiments with various nMOSFETs

nMOSFET	L3 mH	L1 mH	Average DC mA	Out Vpp
BS898	2x6.8 Serial	6.8	9	81
BS170	2x6.8 Serial	6.8	6	70
BS170	1x6.8	6.8	7	77
BS295	1x6.8	6.8	8	83
BSH1052.215	1x6.8	6.8	14	96

Table 1: Data with various nMOSFETs, Supply 7.4V

Comment:

At this very low frequency of 40kHz almost any nFET or nMOSFET can be applied!

5. Comparison with standard +/-5V UST Drive and Class E Amplifier

5.1. With +/-5V at UST Speaker

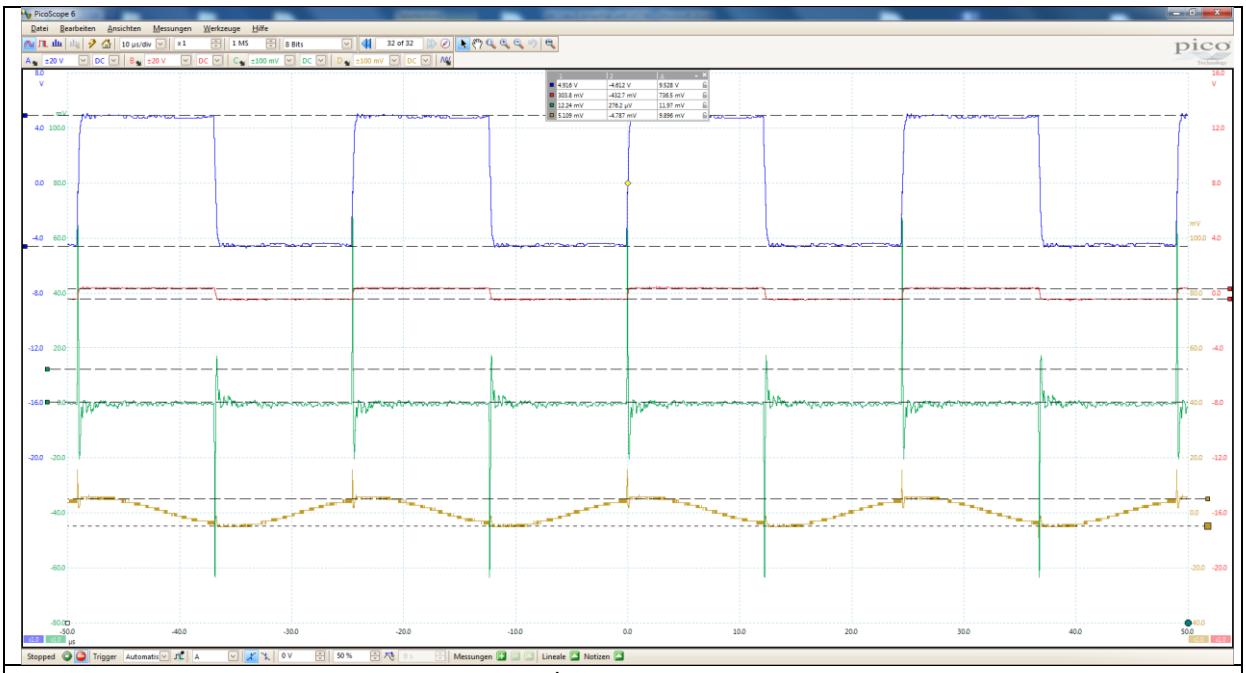

Fig .4: Experimental Data, Time Scale 20usec/Div, LP 5MHz, Maximum at 41.6kHz
Top A: Supply UST, +/-20V, about 10Vpp
Middle B: Voltage at UST,+/-20V, **Probe 10x1**, 7.5Vpp (why not 10Vpp?)
Below C: Voltage at 1Ohm Shunt in GND Line, +/-100mV, not activated
Bottom D: Received US Signal, distance 0.3m, not inline, +/-100mV: 9.8mV

5.2 With 5V Supply at Class E Amplifier

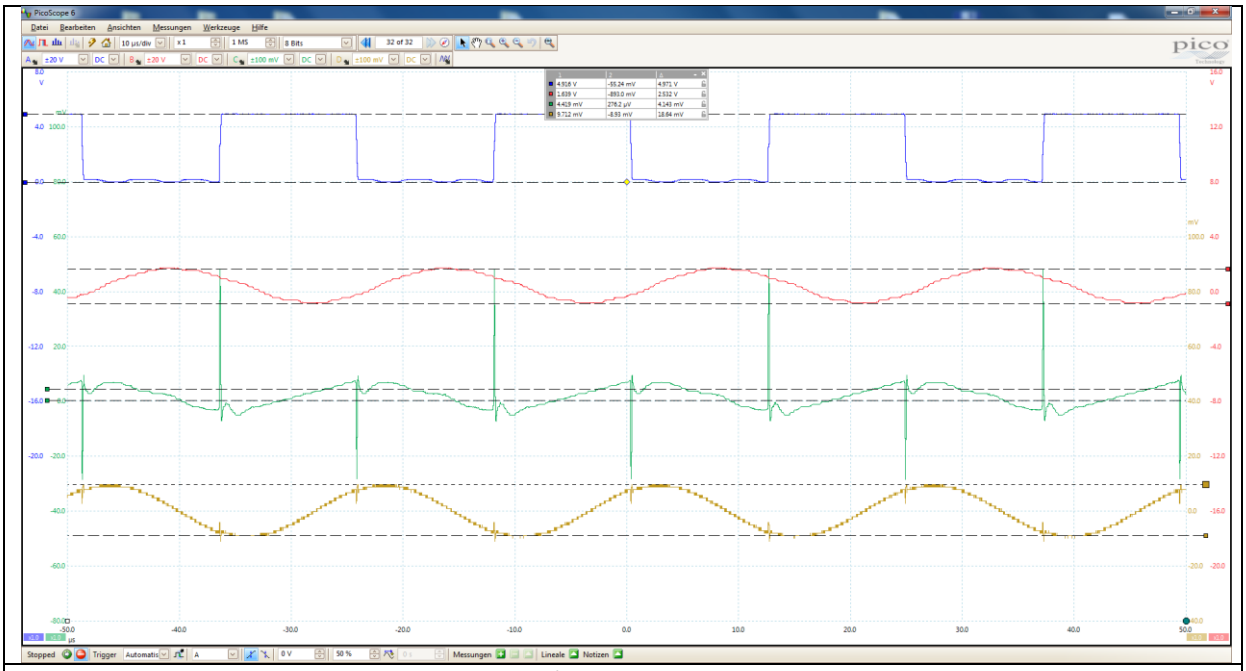

Fig. 5: Experimental Data, Time Scale 20usec/Div, LP 5MHz, Maximum at 41.6kHz
Top A: Gate, +/-20V, 0 to 5V
Middle B: Voltage at UST,+/-20V, **Probe 10x1**, 25Vpp
Below C: Voltage at 1Ohm Shunt in GND Line 4.3mV= 4.3mA
Bottom D: Received US Signal, distance 0.3m, not inline, +/-100mV: 18.64mV

5.2. Class E-Amplifier with 7.4V Supply:

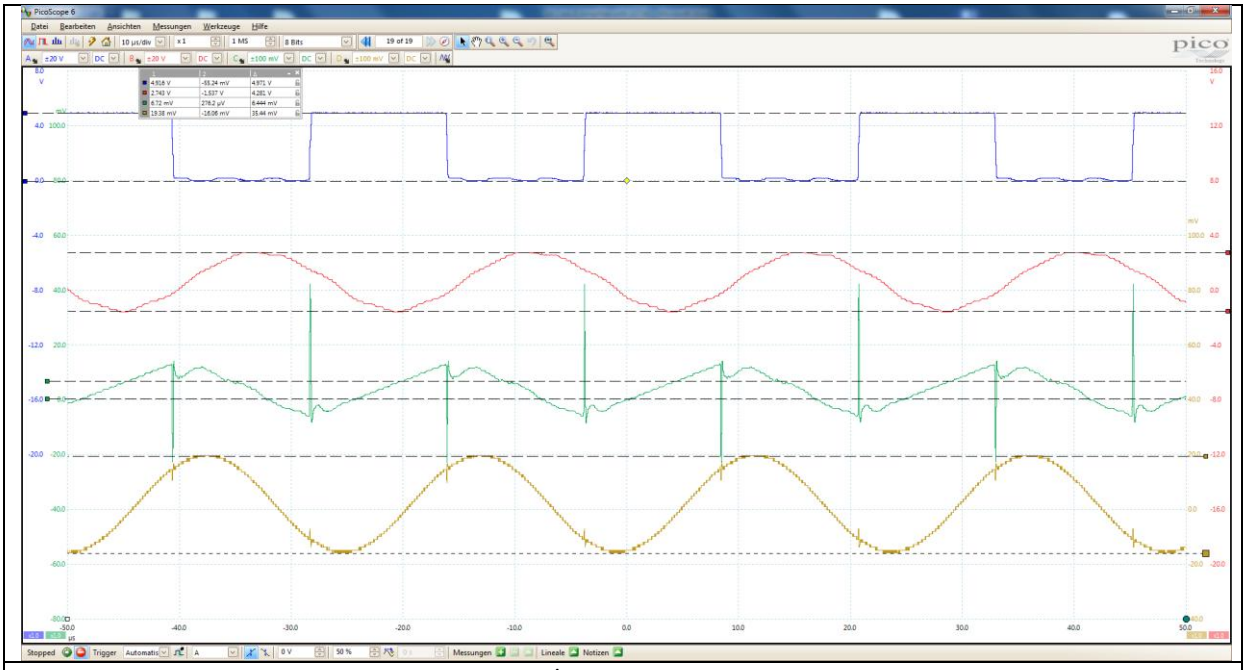

Fig. 6: Experimental Data, Time Scale 20usec/Div, LP 5MHz, Maximum at 41.6kHz
Top A: Gate, +/-20V, 0 to 5V
Middle B: Voltage at UST+/-20V, **Probe 10x1**, 42Vpp (about 15VRMS, below specified 20VRMS, ok)
Below C: Voltage at 1Ohm Shunt in GND Line 6.4mV= 6.4mA
Bottom D: Received US Signal, distance 0.3m, not inline, +/-100mV: 35. 4mV

6. US Supply vs. received US-Signal

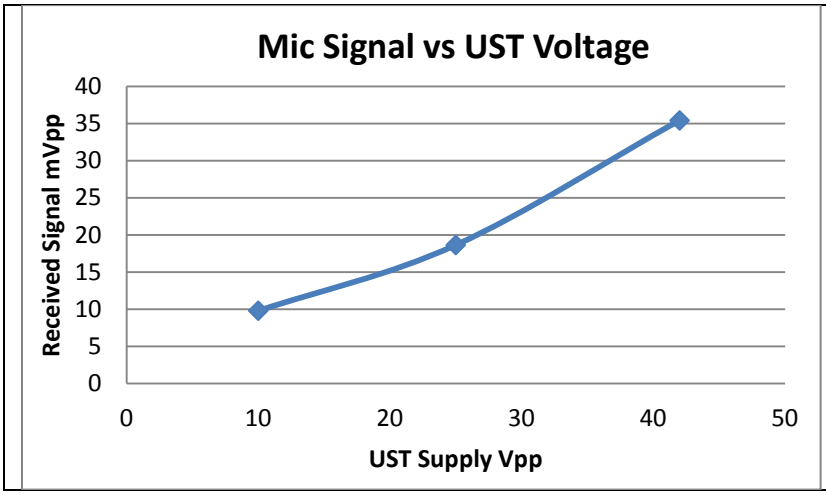

Fig.6: Characteristics UST-Supply vs. Received Signal

Input 10Vpp: by Buffer

Input 25Vpp: by Class E Amplifier, supplied by 5V

Input 42Vpp: by Class E Amplifier, supplied by 7.4V

Comments:
- 10Vpp out of a 5V Supply can be realized by a two Inverting/Noninverting Buffers.
- 20Vpp out of a 5V Supply can be realized by a voltage Doppler, but it consumes about 5mA all the time, also if the US-Speaker is not activated.
- 42Vpp out of a 7.4V Supply can be realized by the tricky Class E-Amplifier. It consumes 16mA, but only if running!
- 42Vpp means 15Vrms, which is < 20Vrms (maximum spec for UST-40)

WARNINGS: During start-up, the output is not stable within the first 0.5msec!