

How should one design a 50kHz, 1200VA transformer as per IEC 61558 ?

Technical specification relevant only to design

Electrical data and diagram

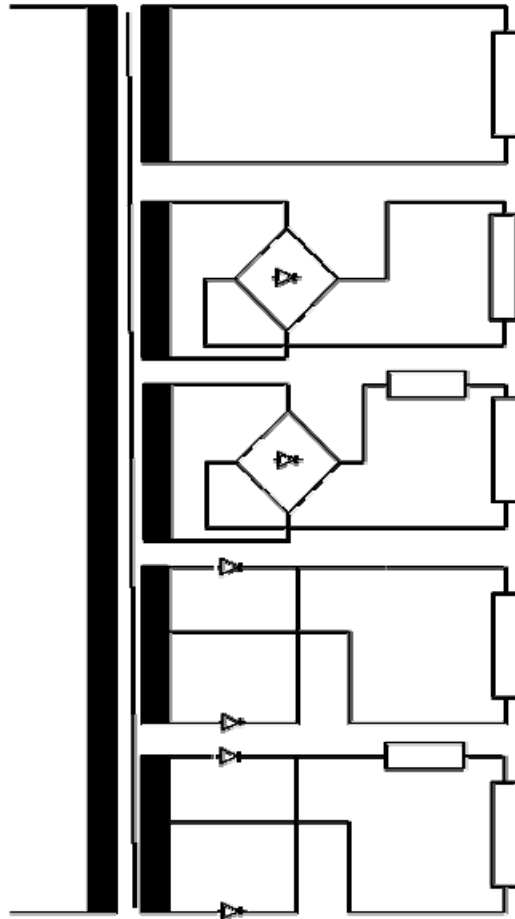
Input voltages	Max. 280Vac, square-wave
Frequency	50kHz
Nominal output voltage 1	24Vac 10Aac
Nominal output current 1	
Nominal output voltage 2	24Vdc, bridge rectifier with R load 10Adc
Nominal output current 2	
Nominal output voltage 3	24Vdc, bridge rectifier with RL load 10Adc
Nominal output current 3	
Nominal output voltage 4	24Vdc, central tapping rectifier with R load
Nominal output current 4	10Adc
Nominal output voltage 5	24Vdc, central tapping rectifier with RL load
Nominal output current 5	10Adc

Ambient and operating conditions:

Ambient temperature	40°C
Mode of operation	Continuous
Test conditions	Non inherently short-circuit proof

Specification

- Insulation class E



Criteria for design

IEC 61558

A high-frequency transformer with non inherently short-circuit proof as per IEC 61558 is equipped with a safety. Very often we arrive at a combined protection solution consisting of a thermal cutout in the transformer and cut-out electronics in the cycled mains power unit to protect against overload and short-circuit. For this reason, short-circuit and overload are not design criteria. The criterion for design with regard to IEC 61558 is only temperature θ **nominal**.

Insulation class	A	E	B	F	H
Max winding temperature in test θ max (° C)	200	215	225	240	260
Max winding temperature in nominal operating mode θ nominal (° C)	100	115	120	140	165

Insulation class

Max winding temperature in nominal operating mode = 115°C

Max winding temperature in test mode = 215°C

Insulation class E is prescribed.

Criterion for design

Normally, high-frequency transformers have very low regulation and are designed according to the prescribed temperature rise.

Since these transformers are manufactured almost exclusively using ferrite, the optimum operating temperature is around 100°C.

Bobbin unit

In order to protect the transistors, high-frequency transformers should be manufactured for low scatter, with single-chamber bobbin units. For this reason, we very often arrive at dual-wire or interleaved windings.

Ferrite quality

Since the optimum operating temperature of ferrite for high-frequency transformers over 100VA is around 100°C and their ambient temperature is between 40°C and 70°C, our design assumption must be for an temperature rise of between 30°K and 60°K. If the core losses in relation to temperature rise are not economically acceptable, then the computer program will optimise or reduce induction automatically. But this does indicate that the selected ferrite quality is not optimized.

Induction and ferrite quality

High-frequency transformers are equipped almost exclusively with ferrite. The program calculates both the active and the reactive core losses by hypothesizing the ferrite type, the frequency, the form of input voltage, induction and core temperature. The induction should be selected such that the transformer does not saturate at maximum input voltage and maximum core temperature.

Copper additional losses

With a high-frequency transformer, the distinctions are drawn between the following additional losses in a winding, over and above the dc-current losses:

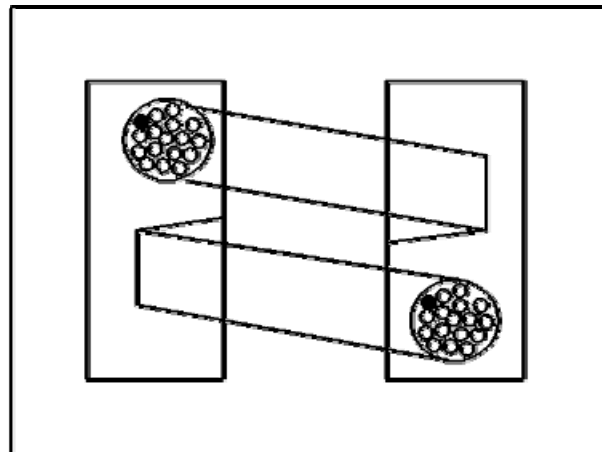
- Eddy current losses
- Displacement losses
- Proximity effect losses
- Losses due to circulating currents through the parallel-connected wires.

Additional losses are smaller in the case of a winding that takes up only 30-60% of the available winding space. For that reason, one should always set the input for the **filling factor** between 0.3 and 0.6 for purposes of automatic core selection.

The input for **Rac/Rdc** will limit the extent of additional losses (eddy current losses and displacement losses). The computer program selects a high enough number of parallel-connected wires for the eddy current losses and displacement losses to fall short of the prescribed value for **Rac/Rdc**. For that reason, the input for **Rac/Rdc** is also used for monitoring of parallel-connected wires. The value is normally set between 1.5 and 5.

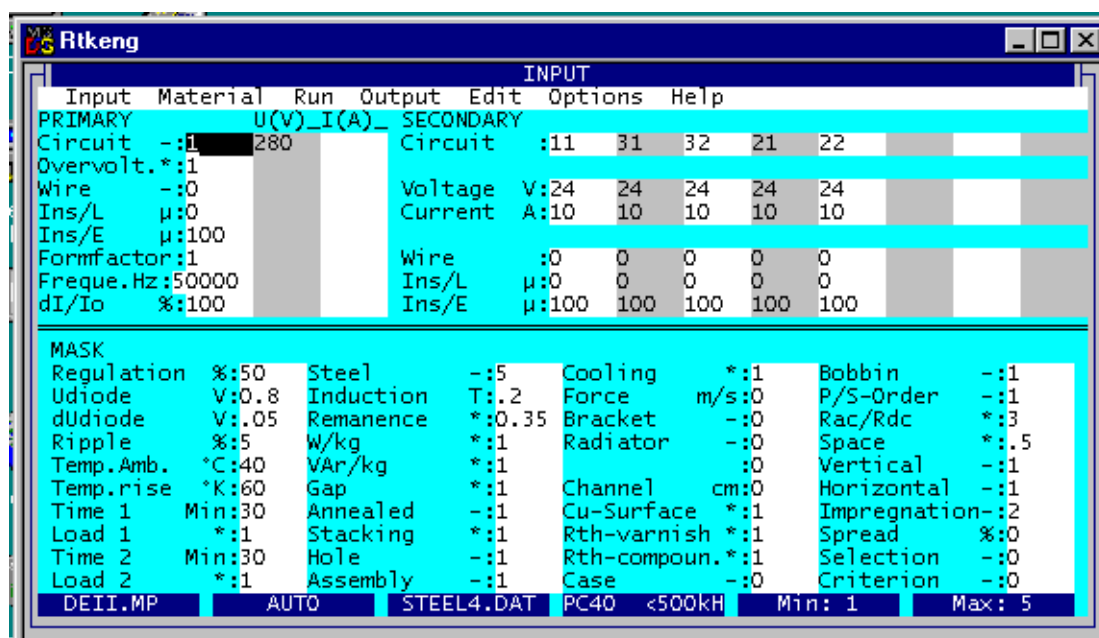
Proximity effects can be reduced by means of the **Spread** input. Another option for reducing proximity effects is to select wires with thicker insulation.

Losses of circulating currents through the parallel-connected wires are not calculated. It is assumed that these additional losses have been eliminated by suitable design precautions. In particular, it should be ensured, for a given litz, that the twisting for the winding is done such that a given wire has the same position at the input and at the output of the winding.



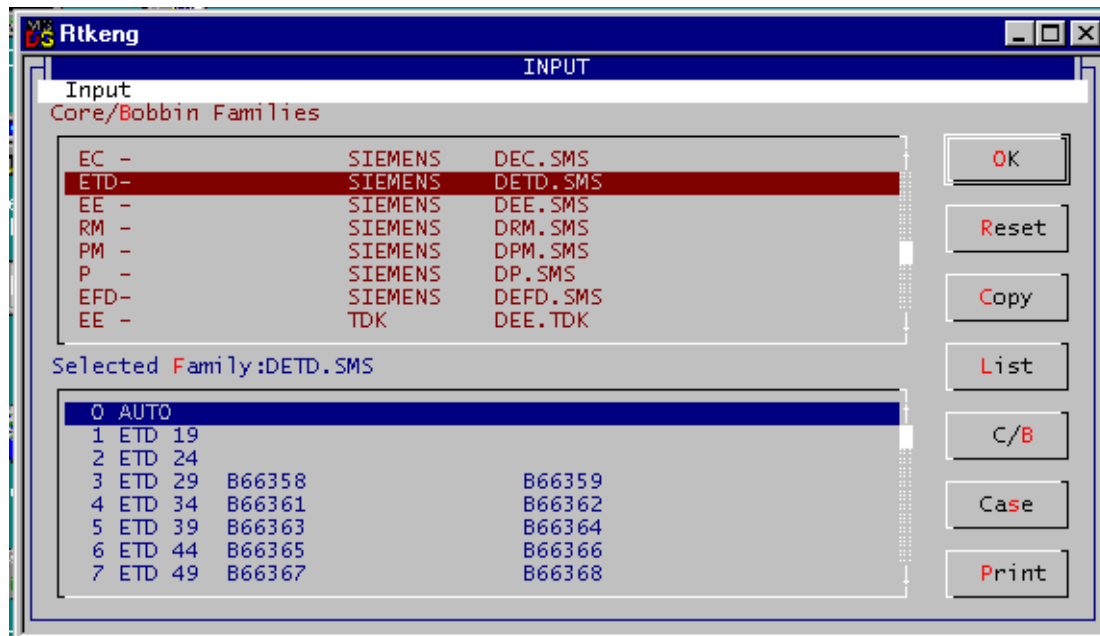
Procedure for design

1. If you are not yet acquainted with Rale design software, please read the text "**How should I design a small transformer?**". Keep a copy of this text within convenient reach whenever performing design work.
2. Fill in the design input mask as follows. If you need any help, press function key F1. There is extensive description for each input field.

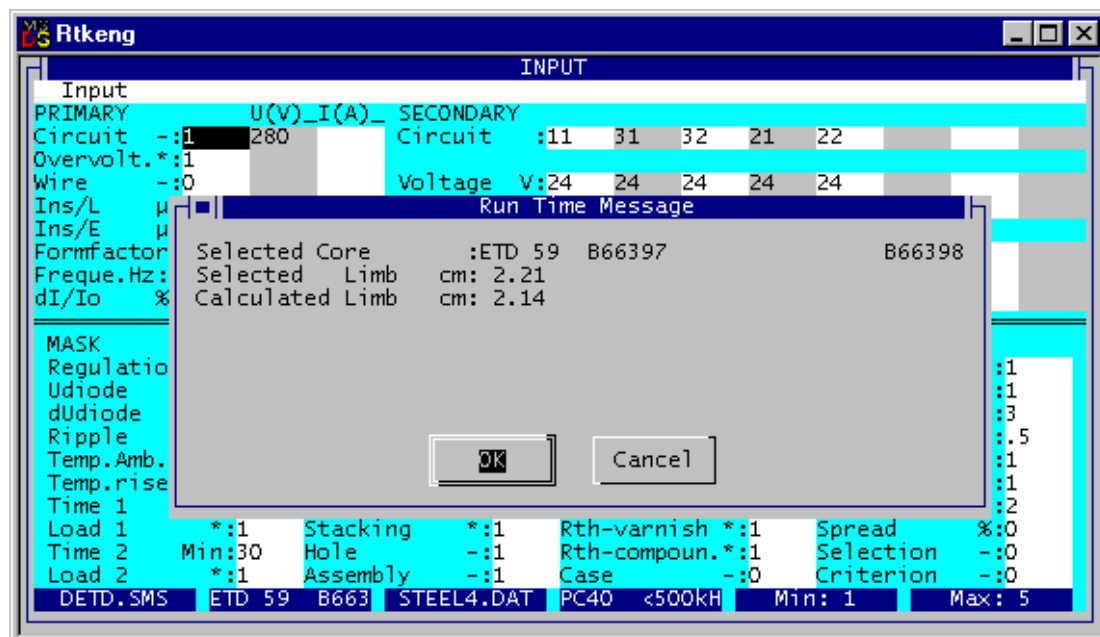


3. The **Selection** input field is set at **0**. This means that the program should search on-line for a suitable core for this application, from your selected core family.
4. Save your input data file. In this specimen design calculation, we saved the input data in input data file **CAL0009E.TK1**. This input data file was

- supplied together with this document. Copy it into the directory in which your Rale demo program is installed.
5. Connect up to the Rale design server.
 6. Load up your input data file.
 7. Now select the core family and the core for automatic search by the computer program.

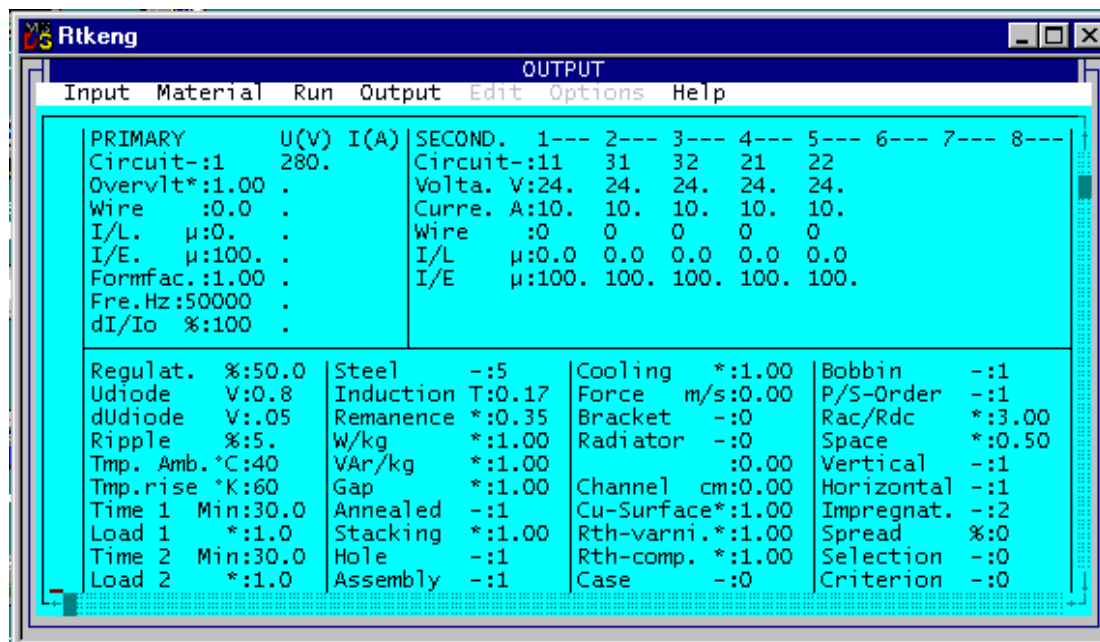
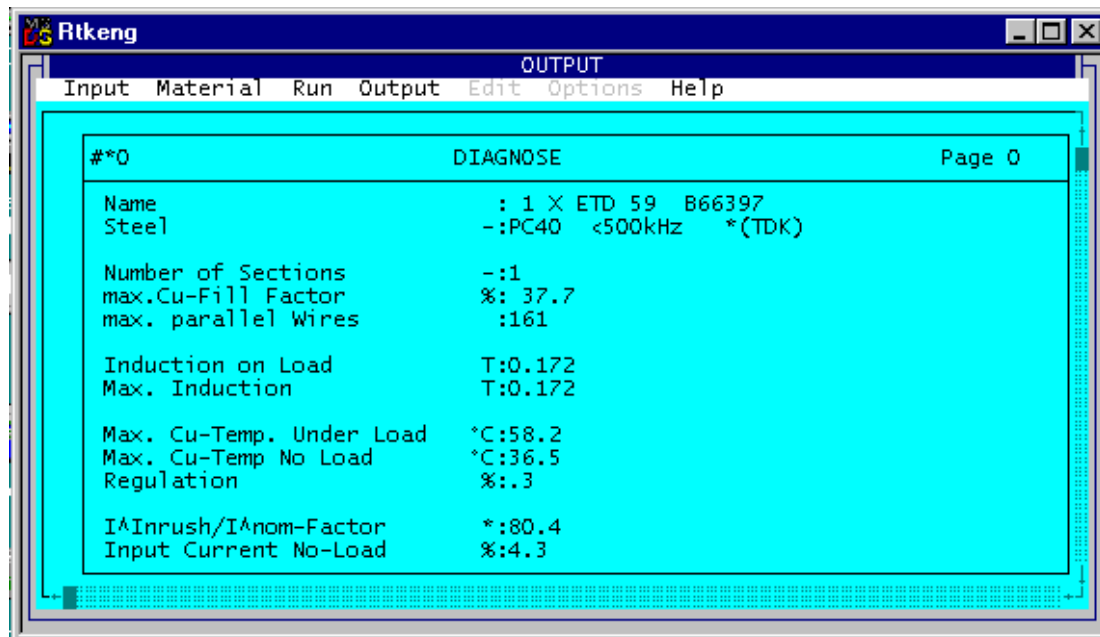


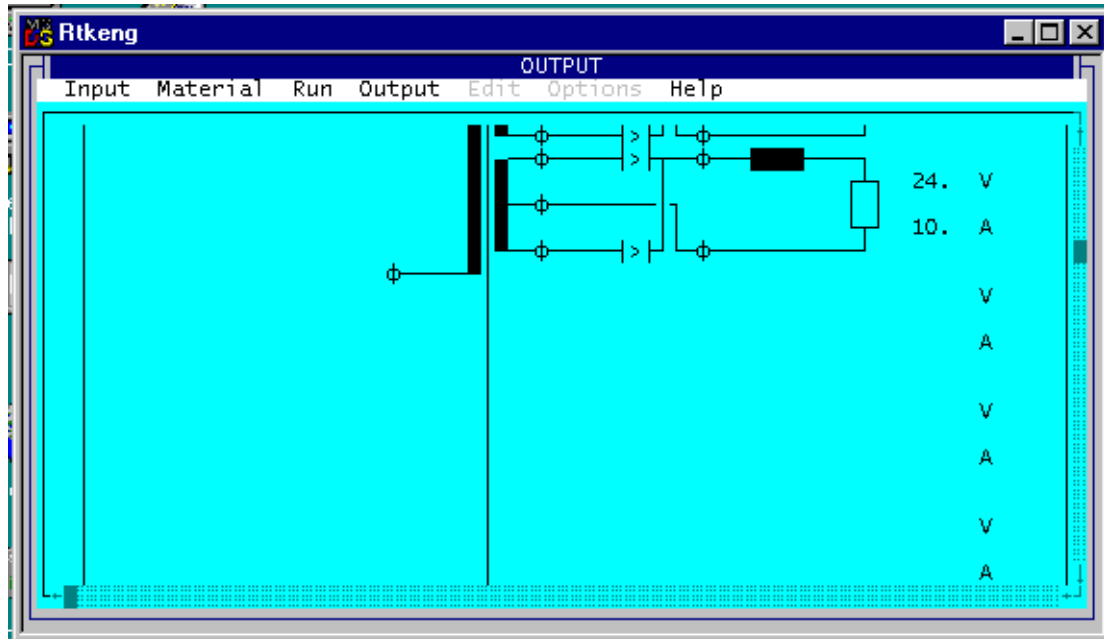
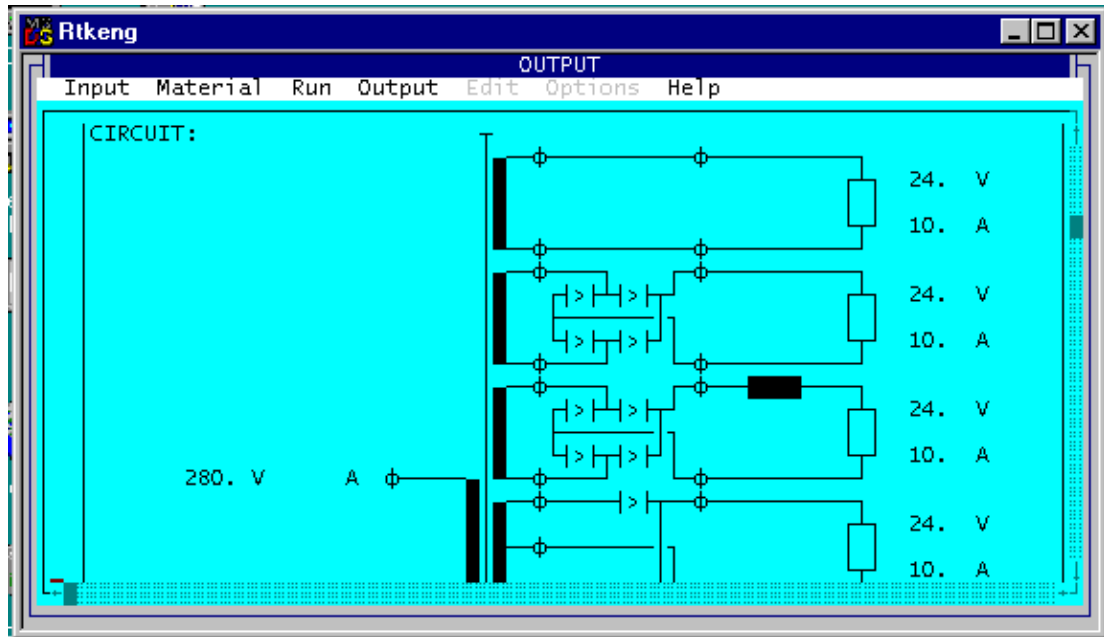
8. Click on **OK**.
9. Start your design work. In the system for automatic selection of the core from your prescribed core family, the program will offer you an adequately sized core for your application. Click on OK in order to accept the core.



On completion of the design work, the following design data will be available

and can be printed on three pages:





Rtkeng OUTPUT

Input Material Run Output Edit Options Help

Name : 1XETD 59 B66397 B66398
 Steel : PC40 <500kHz S(TDK) /1.

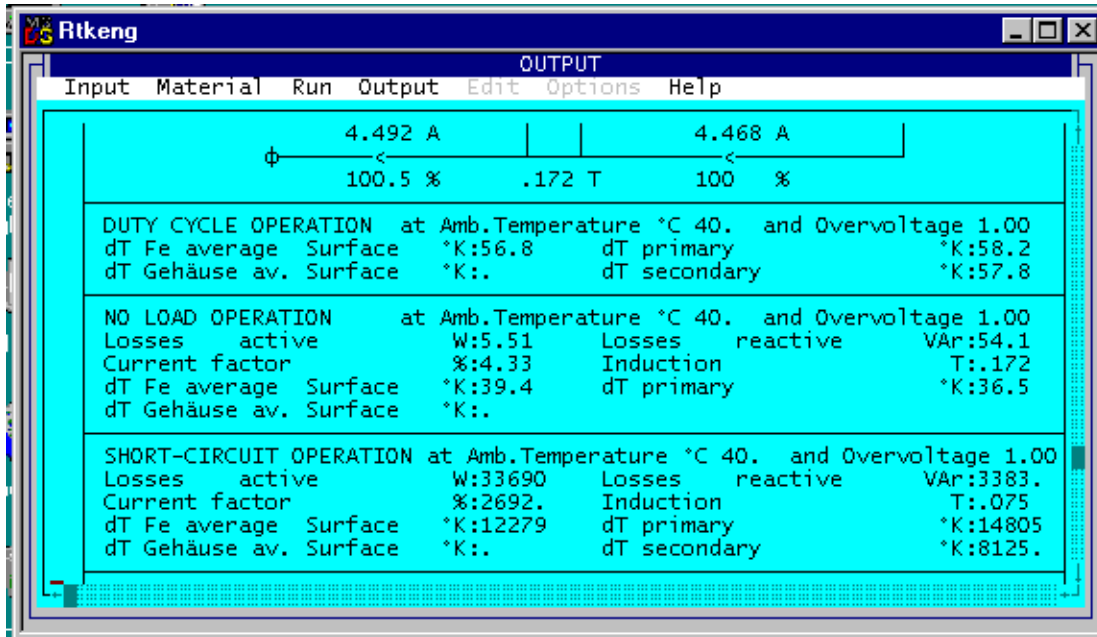
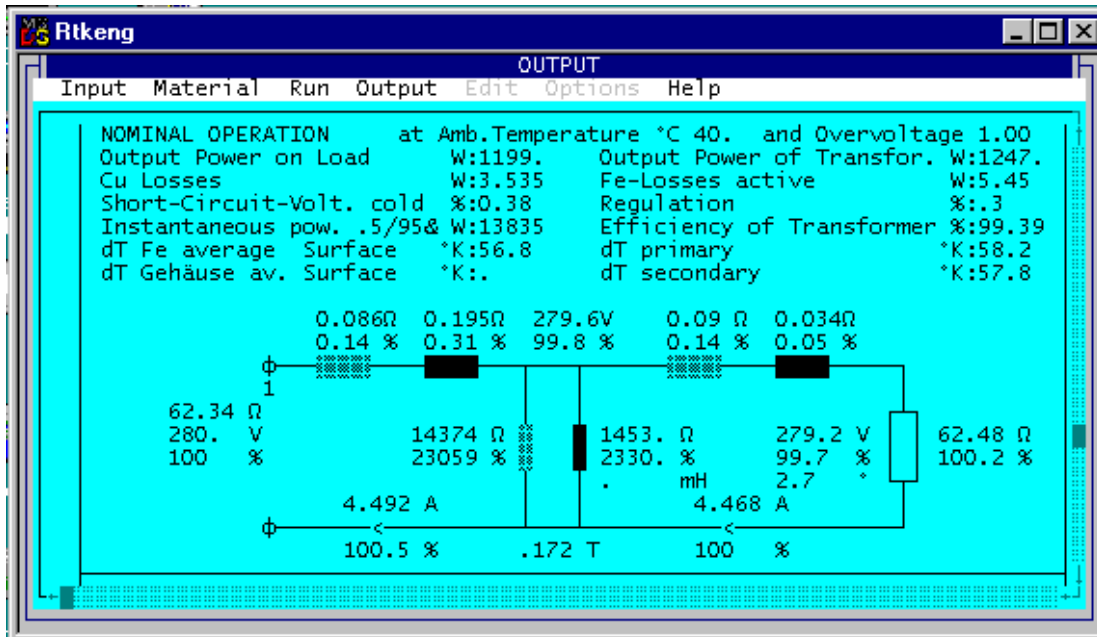
Weight gr:280.01
 Gap total cm:0.000
 A-Limb cm:2.21
 B-Width cm:1.07
 C-Height cm:4.40
 D-Stack cm:2.21
 E-Yoke 1 cm:0.92
 F-Yoke 2 cm:0.86
 G-Hole cm:0.00
 Radiator Fin :0
 Radiator Chan. :0

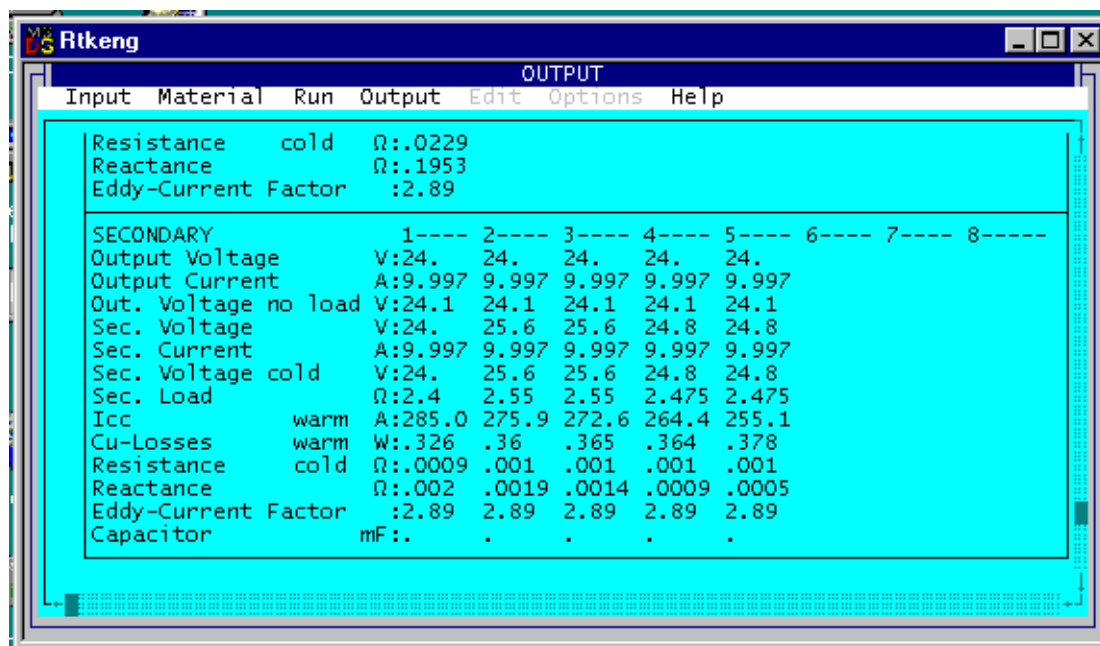
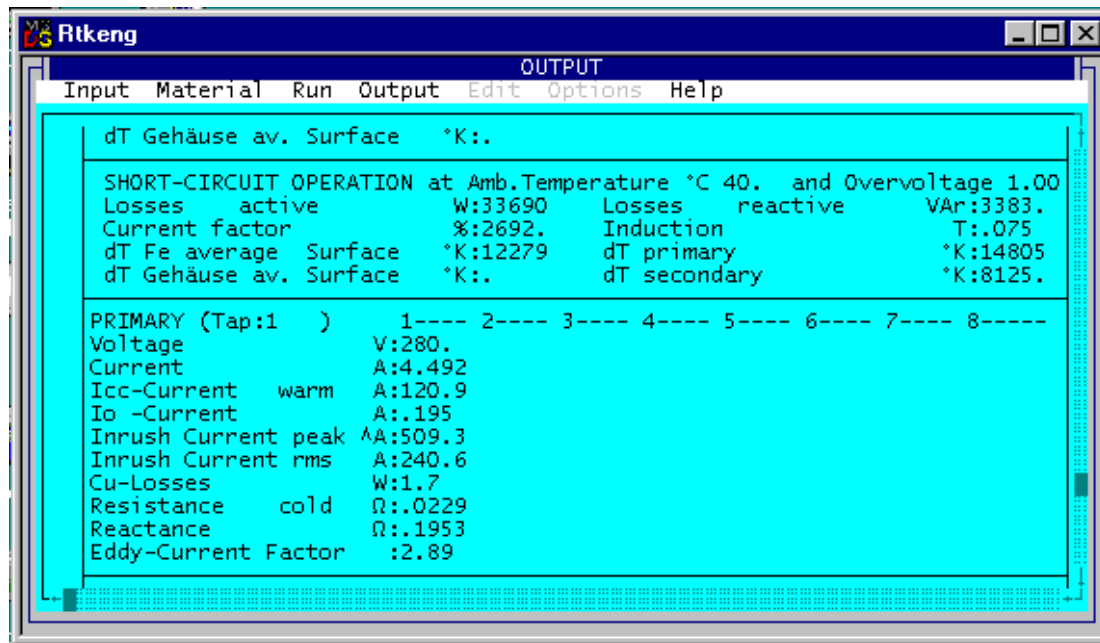
a1 cm:2.48
 a2 cm:4.24
 d1 cm:2.48
 d2 cm:4.24
 l cm:4.11
 lp cm:

Rtkeng OUTPUT

Input Material Run Output Edit Options Help

	Typ	Turns	T	WG	WG	Par	W/φ mm	H/φ mm	T/L	L	I/L μ	I/E μ	Weight gr	RWH %
1	1	21.2	0	48.0	48.0	66	.16	.16	216.9	6.46	.	100	20.289	14.
2														
3														
4														
5														
6														
7														
8														
1	11	1.8	0	48.0	48.0	161	.16	.16	216.9	1.36	.	100	4.573	5.3
2	31	1.9	0	48.0	48.0	161	.16	.16	216.9	1.45	.	100	5.041	5.3
3	32	1.9	0	48.0	48.0	161	.16	.16	216.9	1.45	.	100	5.106	5.3
4	21	1.9	0	48.0	48.0	161	.16	.16	216.9	2.8	.	100	10.203	7.4
5	22	1.9	0	48.0	48.0	161	.16	.16	216.9	2.8	.	100	10.577	7.4
6														
7														
8														





10. This is followed by checking of the design data.

- The program has reduced the entered induction from 0.2T to 0.172T. This is an indication that at the selected induction of 0.2T, core losses would be too high by comparison with copper losses. An improvement could be achieved by increasing the core cooling surface area or by using a higher grade of ferrite.
- We now check the winding data and the filling factor (37.7% < 100%).
- The maximum temperature of the windings is $40^{\circ}\text{C} + 58.25^{\circ}\text{K} = 98.2^{\circ}\text{C} < 115^{\circ}\text{C}$.
- The number of parallel-connected wires with 0.15 mm diameter is 66 and 161. Commercial considerations prompt us to select a litz of 50 wires of 0.16 mm diameter for the primary and a litz of 175 wires with 0.16 mm for all secondary windings. This operation must be performed manually in the

test mode.

- In the test mode, furthermore, the number of windings of the secondary is manually rounded up from 1.9 to 2 turns. This will result in approximately 5% higher output voltage.

The screenshot shows the Rtkeng software interface with a 'TEST' window. The window contains a table with columns for 'Input', 'Material', 'Run', 'Output', 'Edit', 'Options', and 'Help'. The table is divided into 'PRIMARY' and 'SECONDARY' sections. The 'PRIMARY' section has columns 1-8, and the 'SECONDARY' section has columns 1-8. The 'Run' column (column 2) is highlighted in blue. The 'Output' column (column 4) is highlighted in green. The 'Edit' column (column 5) is highlighted in green. The 'Options' column (column 6) is highlighted in green. The 'Help' column (column 7) is highlighted in green. The 'Input' column (column 1) is highlighted in blue. The 'Material' column (column 2) is highlighted in blue. The 'Run' column (column 3) is highlighted in blue. The 'Output' column (column 4) is highlighted in blue. The 'Edit' column (column 5) is highlighted in blue. The 'Options' column (column 6) is highlighted in blue. The 'Help' column (column 7) is highlighted in blue. The 'Input' column (column 1) is highlighted in blue. The 'Material' column (column 2) is highlighted in blue. The 'Run' column (column 3) is highlighted in blue. The 'Output' column (column 4) is highlighted in blue. The 'Edit' column (column 5) is highlighted in blue. The 'Options' column (column 6) is highlighted in blue. The 'Help' column (column 7) is highlighted in blue.

Input	Material	Run	Output	Edit	Options	Help
PRIMARY	1	2	3	4	5	6
Turns	: 22.					
Family	: 0					
Number	: 48					
Parallel	: 75					
Ins/L	μ: 0.0					
φ-thic	mm: 0.16					
φ-wide	mm: 0.16					
Layers	: 7.59					
SECONDARY	1	2	3	4	5	6
Turns	: 2.	2.	2.	2.	2.	
Family	: 0	0	0	0	0	
Number	: 48	48	48	48	48	
Parallel	: 150	150	150	150	150	
Ins/L	μ: 0.0	0.0	0.0	0.0	0.0	
Load s.	Ω: 2.4	2.55	2.55	2.475	2.475	
φ-thic	mm: 0.16	0.16	0.16	0.16	0.16	
φ-wide	mm: 0.16	0.16	0.16	0.16	0.16	
Layers	: 1.38	1.38	1.38	2.76	2.76	
U sec	V: 25.37	25.37	25.37	25.37	25.37	
U0 sec	V: 25.45	25.45	25.45	25.45	25.45	
I sec	A: 10.57	9.91	9.91	10.23	10.23	
Tap on	-: 1.00					
U input	*: 1.00					
FREQ.	Hz: 50000					
T amb.	°C: 40.0					
t1 on Min:	30.0					
Load 1	*: 1.00					
t2 on Min:	30.0					
Load 2	*: 1.00					
STEEL	-: 5					
Margin	cm: 0.14					
Case	-: 0					
RWH	%: 39.8					
dT-rise	*K: 58.					
dU	%: .3					
IO	%: 3.88					
Ii ^A /In ^A	: 70.7					
P Fe	W: 4.79					
P Cu	W: 4.03					
Bn	T: .166					
B0	T: .166					
Br	T: .058					
ETD 59	B663					

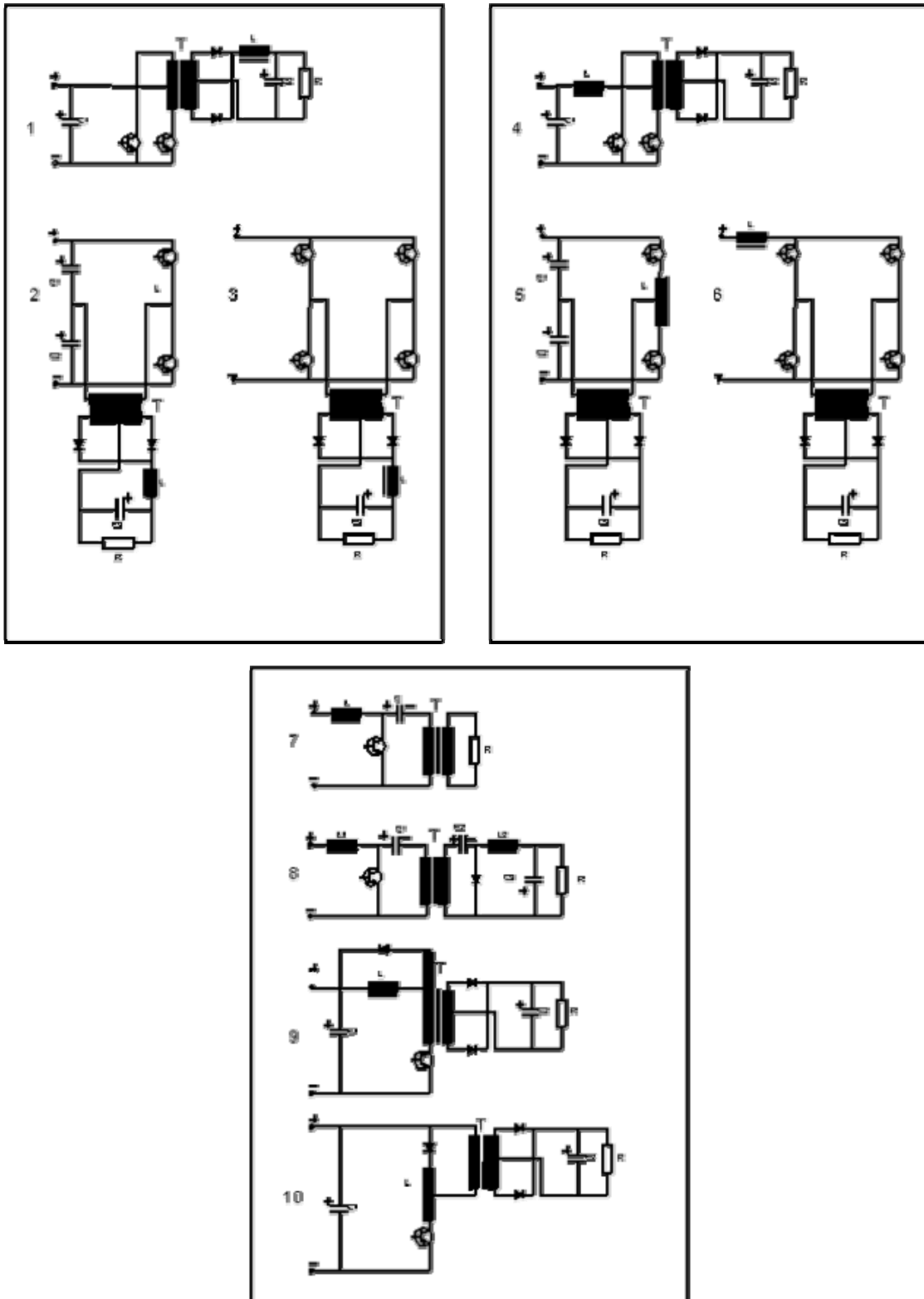
11. If the design data is not satisfactory, then there are two ways by which we can implement the desired correction:

- You can return to the input mask (function key F2), correct the input data and redesign the transformer.
- Or you can access the test program (function key F5), modify the designed transformer manually and redesign the transformer by that means.

12. On completion of the design work, you can print out the design data on-line, or save it on your local PC and print it out off-line. The output data file from this design example, CAL0009E.TK2, is supplied together with this document. Copy it into the directory in which your Rale demo program is installed.

Tips & Tricks

Typical circuits



Upon entering the input voltage, we assume that there is an impressed voltage for circuits 1, 2 & 3.

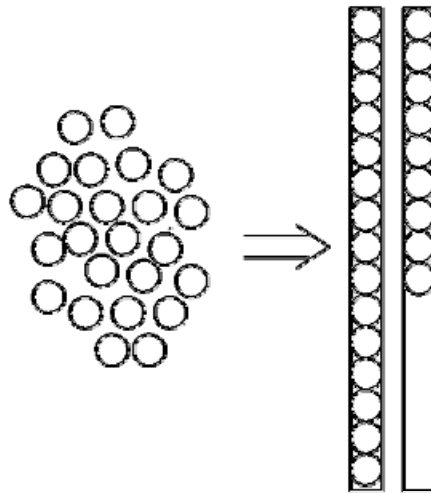
The input current for circuits 4, 5 & 6 is impressed. For these circuits, we have to

start by determining the primary input voltage, the secondary voltage and the secondary current manually in order to be able to use the computer program to design the transformer.

Circuits 7 to 10 are a combination of supply with impressed voltage and supply with impressed current, and are treated as circuits with impressed current.

Copper strip instead of litz

A litz can be replaced by a copper strip. The strip thickness should correspond to the wire diameter of the litz. Strip width should be matched to the width of the bobbin. The number of strips connected in parallel is determined in accordance with the following illustration.



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