

How do we design a rectifier safety transformer for feed to voltage controllers of 5Vdc,1Adc and 2x12Vdc,0.1Adc with RC-loadin accordance with IEC 61558 ?

Technical specification relevant only to design

Electrical data and diagram

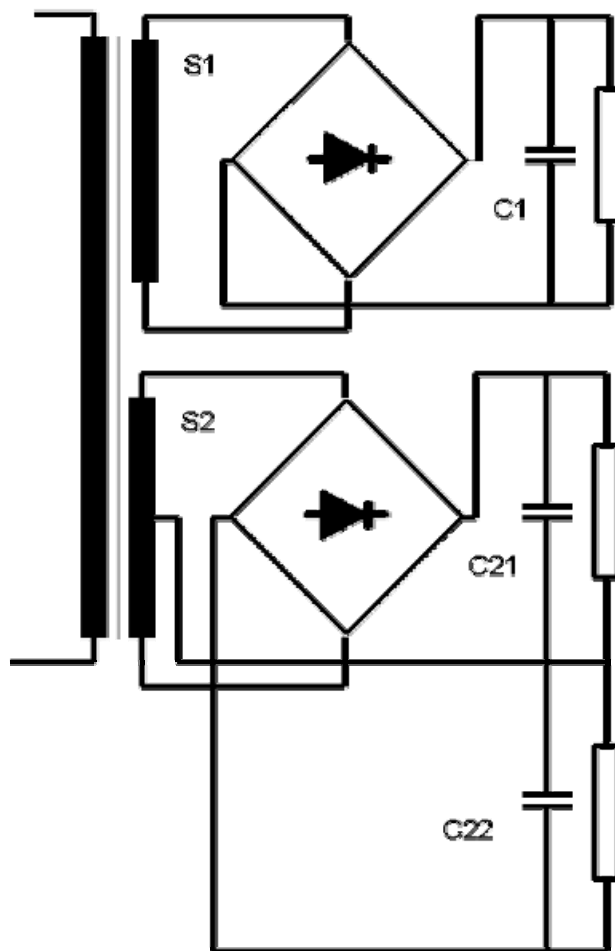
Input voltage	: 230V, +6%, -10%, sinusoidal
Frequency	: 50Hz
Min. output voltage 1	: 8Vdc, at -10% of input voltage
Nominal output voltage 1	: max.14Vdc, at +6% of input voltage
Nominal output current 1	: 1Adc, RC load
Min. output voltage 2	: 2x15Vdc, at -10% of input voltage
No-load output voltage 2	: max. 2x25dc, at +6% of input voltage
Nominal output curren 2	: 0.1Adc, RC load
Voltage ripple	: max 5%

Ambient and operating conditions:

max. 2x25dc, at +6% of input voltage	40°C
Mode of operation	Continuous, for 5V and 2x12V voltage controller feed
Test conditions	Not short-circuit proof transformer

Specification

- Safety transformer as per IEC 61558
- Insulation class E



Criteria for design

IEC 61558

A transformer which is not required by IEC 61558 to be short-circuit proof is manufactured without protection. However, the manufacturer is obliged to inform the user of the required safety precautions by means of which the transformer must be protected in operation. In this case, the transformer must be protected by means of a miniature fuse as per IEC 127: the type and nominal current of the fuse must be stated on the transformer's information label.

The procedure for testing is prescribed as follows in accordance with paragraphs 14.2 and 15.3.3:

1. Firstly, the transformer is loaded in accordance with paragraph 14.2 with the nominal load resistance and at $1.06 \times$ the nominal input voltage until permanent operating temperature is achieved. In this context, the temperature of the windings must not exceed the value of θ **nominal**.
2. Immediately after this test, in accordance with paragraph 15.3.3, all secondaries are loaded at $K \times$ the nominal current of the fuse for time period T. Time period T is the longest pre-arcing period of the fuse, caused by $K \times$ the nominal current of the fuse. After lapse of time period T, the temperature of the windings must not exceed the value of θ **max**. The typical values for a slow-blow fine fuse as per IEC 127 are:
 $T = 30$ minutes
 $K = 2.1$

Here, the temperature of the windings must not exceed θ_{max} and that of the case must not exceed the values set out on the following table.

In the case of transformers with regulation greater than 20%, switch-on current is not a criterion for our choice of fuse. Consequently, we can select a rapid fuse, which will result in a much shorter pre-arcing time.

3. Finally, all output windings are short-circuited. at 1.06 x the nominal input voltage, the integral thermal cutout should actuate, before the temperature exceeds the value of θ_{max} as per the following table:

Insulation class	A	E	B	F	H
Typical pre-arcing time T (in minutes)	30	30	30	30	30
Typical factor K	2.1	2.1	2.1	2.1	2.1
Max winding temperature in test θ_{max} (° C)	200	215	225	240	260
Max winding temperature in nominal operation mode $\theta_{nominal}$ (° C)	100	115	120	140	165

Insulation class

Max winding temperature in nominal operation mode = 115°C

Max winding temperature in test mode = 215°C

Insulation class E is prescribed.

Output voltage

A rectifier transformer with RC load, for which the minimum and maximum output voltages are described, must adhere to the prescribed tolerances. For that reason, the transformer is firstly designed in accordance with the criterion of **regulation (criterion = 1)** and then tested to IEC in the test program.

Rectifier transformers with RC load can only be designed in accordance with the criterion regulation.

The output voltages of 2x15Vdc are grouped together as one single voltage of 30Vdc and calculated as the output voltage of a shunt rectifier. After our design work, we must provide for a tap in the middle of the calculated number of windings. If the designed value amounts to that of capacity C, then connectors C21 and C22 must have the value of 2*C.

Regulation (voltage boosting)

For purposes of designing the transformer in accordance with the **regulation** criterion (voltage boosting), we have to enter the value for boosting the voltage of the secondary voltages. Regulation is calculated as follows by means of the direct current voltages:

The transformer is designed for 207Vac. In this context, the output voltages under load in the hot state must not fall short of the values of 8Vdc and 2x15Vdc. The maximum no-load voltages must not exceed the levels of 14Vdc and 2x25Vac at an input voltage of 243.8Vac.

At an input voltage of 207Vac, the no-load voltages should be below the levels of $14 \cdot 207 / 243.8 = 11.9\text{Vdc}$ and $2 \cdot 21.2\text{Vdc}$. This corresponds to a regulation of the output voltage of $100 \cdot (11.9 - 8) / 8 = < 50\%$. The increase in the secondary voltages (regulation)

Should be a maximum of < 20-25% as per the following table:

Regulation of secondary voltage %	Regulation of the DC voltage of a single-phase shunt rectifier with RC load %	Regulation of the DC voltage of a triple-phase shunt rectifier with RC load %
1	8-12	5-6
2.5	12-14	7-8
5	14-17	9-10
10	20-25	13-14
15	30-33	17-18
20	37-40	20-22
30	52-54	30-32
40	64-66	41-43
50	80-82	50-53

Output voltage ripple

Output voltage ripple can be prescribed as follows:

$$\text{Ripple} = 100 * (\text{Udcmax} - \text{Udcmin}) / (\text{Udcmax} + \text{Udcmin})$$

The program calculates the magnitude of the required capacity of the smoothing condensers for the prescribed DC voltage ripples.

Bobbin unit

Is this performance range, recourse is had almost exclusively to a double-chamber bobbin unit.

Let's choose a double-chamber bobbin unit .

Impregnation

The bobbin unit or the window of the core is injected under pressure. In this method, we save on the quantity of potting compound with the same voltage resistance as a potted transformer, and we don't need a case.

The winding space of our transformer is injected under pressure. The windings are pressed.

Induction

We select our induction on the basis of a voltage level below the input voltage of -10%, between 1.2 and 1.4.

Procedure for design

1. If you are not yet acquainted with Rale Design software, please read the text: "**How do I design a small transformer?**". You should keep a copy of this text within your reach whenever performing design operations.
2. Fill out the input mask as follows. If you need any help, press function key F1. There is extensive description for each box.

The screenshot shows the RALE Demo software interface. The top window is titled "RALE Demo" and contains an "INPUT" screen. Below it is a "MASK" screen. The INPUT screen has two columns: PRIMARY and SECONDARY. The PRIMARY column contains fields for Circuit, Overvolt.*, Wire, Ins/L, Ins/E, Formfactor, and Freque. The SECONDARY column contains fields for Circuit, Voltage, Current, Wire, Ins/L, and Ins/E. The MASK screen contains a grid of parameters with values and units. At the bottom, there are status fields for DEII.MP, AUTO, STEEL2.DAT, U530-50A, Min: 1, and Max: 5.

PRIMARY	Material	Run	Output	Edit	Options	Help
Circuit	207					
Overvolt.*	:1					
Wire	:0					
Ins/L	μ :0					
Ins/E	μ :0					
Formfactor	:1.11					
Freque	.Hz:50					

PRIMARY	Material	Run	Output	Edit	Options	Help
Circuit	33	33				
Voltage	U:8	30				
Current	A:1	.1				
Wire	:0	0				
Ins/L	μ :0	0				
Ins/E	μ :100	0				

MASK					
Regulation	%:20	Steel	-:3	Cooling	*:1
Udiode	U:0.8	Induction	T:1.35	Force	m/s:0
dUdiode	U:.05	Remanence	*:0.35	Bracket	-:0
Ripple	%:5	W/kg	*:1	Radiator	-:0
Temp.Amb.	$^{\circ}$ C:40	UAr/kg	*:1	Channel	cm:0
Temp.rise	$^{\circ}$ K:80	Gap	*:1	Cu-Surface	*:1
Time 1	Min:30	Annealed	-:0	Rth-varnish	*:1
Load 1	*:1	Stacking	*:1	Rth-compoun.	*:1
Time 2	Min:30	Hole	-:1	Case	-:0
Load 2	*:1	Assembly	-:1	Bobbin	-:2
				P/S-Order	-:1
				Rac/Rdc	*:1.05
				Space	*:1.9
				Vertical	-:0
				Horizontal	-:1
				Impregnation	-:4
				Spread	%:0
				Selection	-:0
				Criterion	-:1

DEII.MP AUTO STEEL2.DAT U530-50A Min: 1 Max: 5

3. The input field **selection** contains a value `0`. This means that the program should search on-line for a suitable core for this application, from your choice of core family.
4. Save your input data file. In this design example, the input data was saved in input data **CAL0005E.TK1**. This input data file was supplied together with this document.. Copy it into the directory in which the Rale demo program is installed.
5. Connect up to the Rale design server.
6. Load up your input data file.
7. Now choose the core family from which you want to look for a suitable core for your application. Ensure that the marked core is **AUTO**.

The screenshot shows the RALE Design software interface. The top window is titled "RALE Design" and contains an "INPUT" screen. The screen is titled "Core/Bobbin Families" and shows a list of core families. The selected family is "DEI1.WSR". Below the list, there is a table of core families with columns for core type, dimensions, and weight. At the bottom, there are buttons for OK, Reset, Copy, List, C/B, Case, and Print.

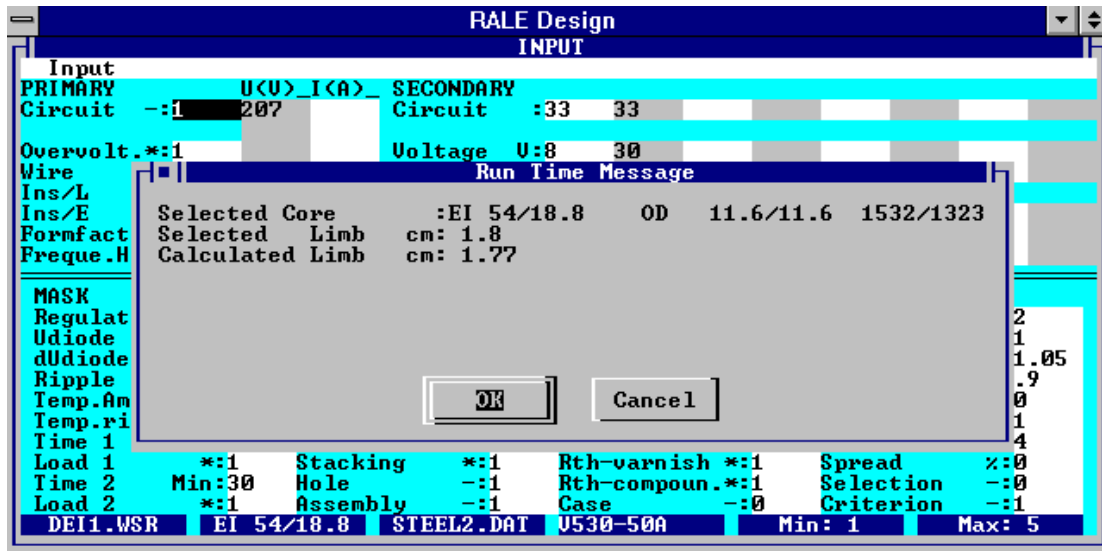
Core/Bobbin Families	Material	Run	Output	Edit	Options	Help
EI -no waste/imper.	MILES&...	DEII.MP				
EI -no waste/metric	MILES&...	DEIM.MP				
EI -Unilam	GB	DUNIL.LH				
EI -38.....150N	WEISSER	DEI1.WSR	:OD			
EI -60.....174	WEISSER	DEI2.WSR	:MS-UL			
EI -42.....120	WEISSER	DEI3.WSR	:LP			
EI -30.....105	WEISSER	DEI4.WSR	:ST			
EI -30.....96	WEISSER	DEI5.WSR	:STk/LPk			

Selected Family: DEI1.WSR

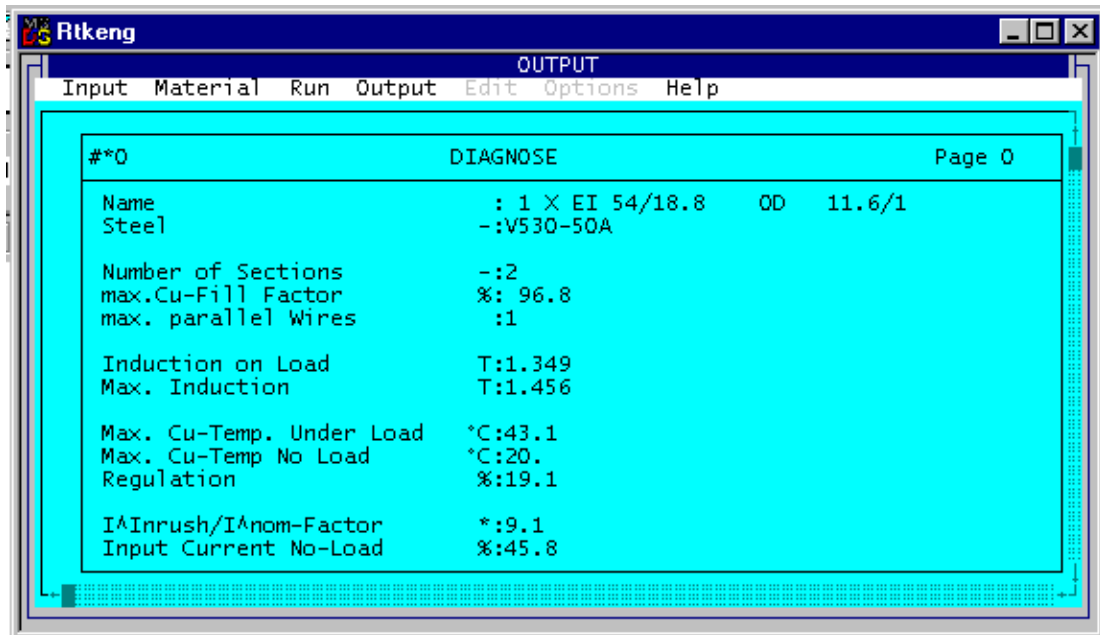
Core/Bobbin Families	Material	Run	Output	Edit	Options	Help
0 AUTO						
1 EI 38/13.5	OD		1570/			
2 EI 42/14.8	OD	9.1/9.1	1527/1713			
3 EI 48/16.8	OD	10.4/10.4	1663/1257			
4 EI 54/18.8	OD	11.6/11.6	1532/1323			
5 EI 60/21	OD	12.7/12.7	1526/1358			
6 EI 60/30.5	OD	12.8/12.8	1854/1904			
7 EI 66/23.0	OD	13.8/13.8	1829/1583			

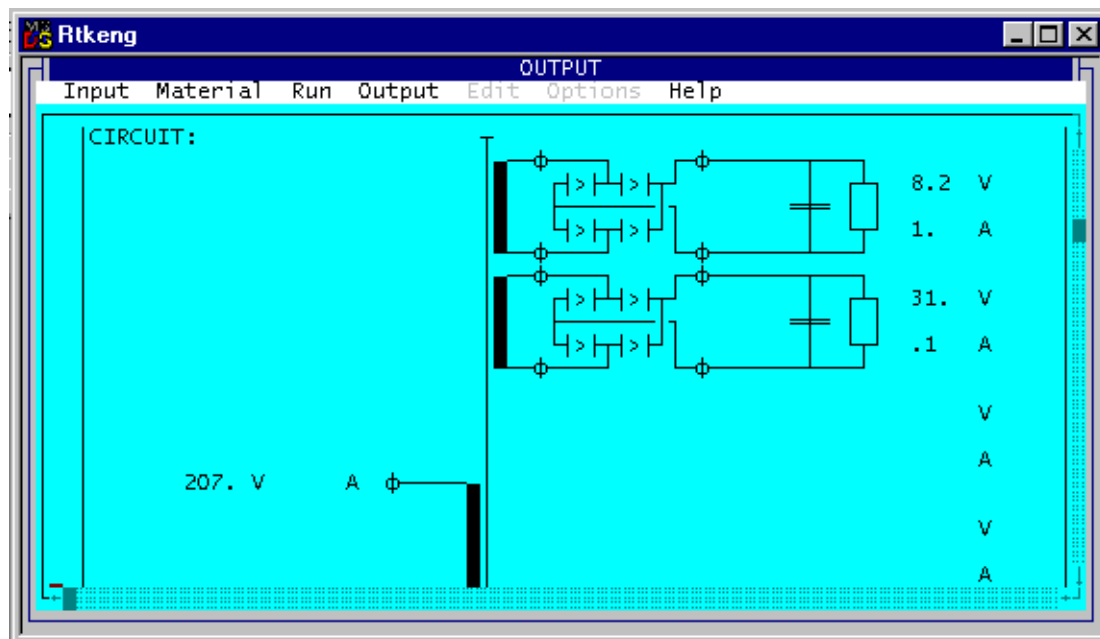
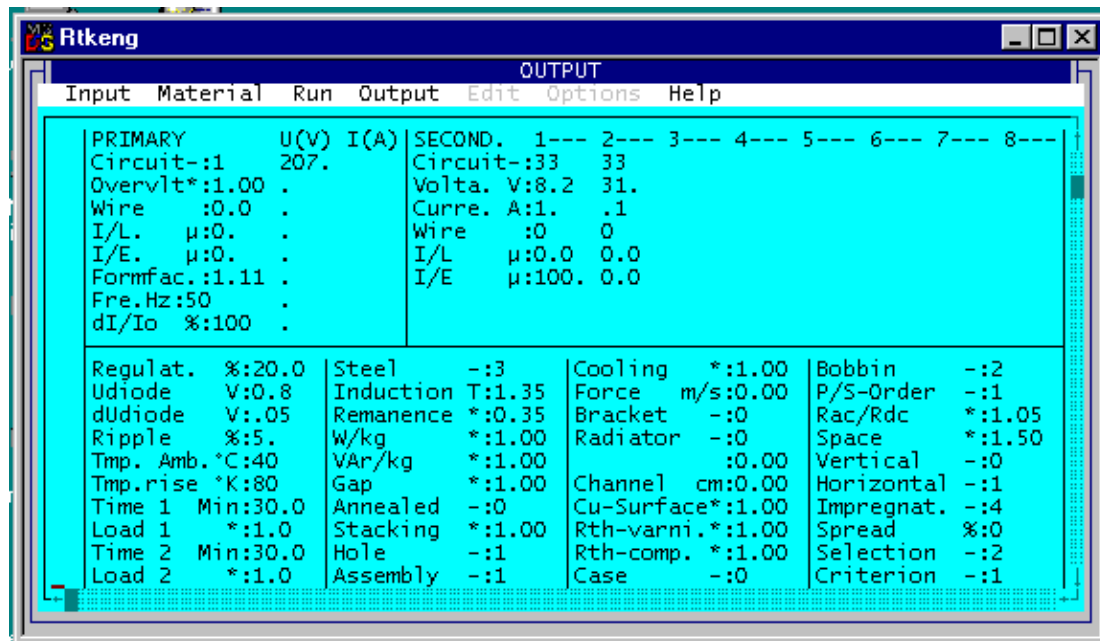
- 8.
9. Click on **OK**.

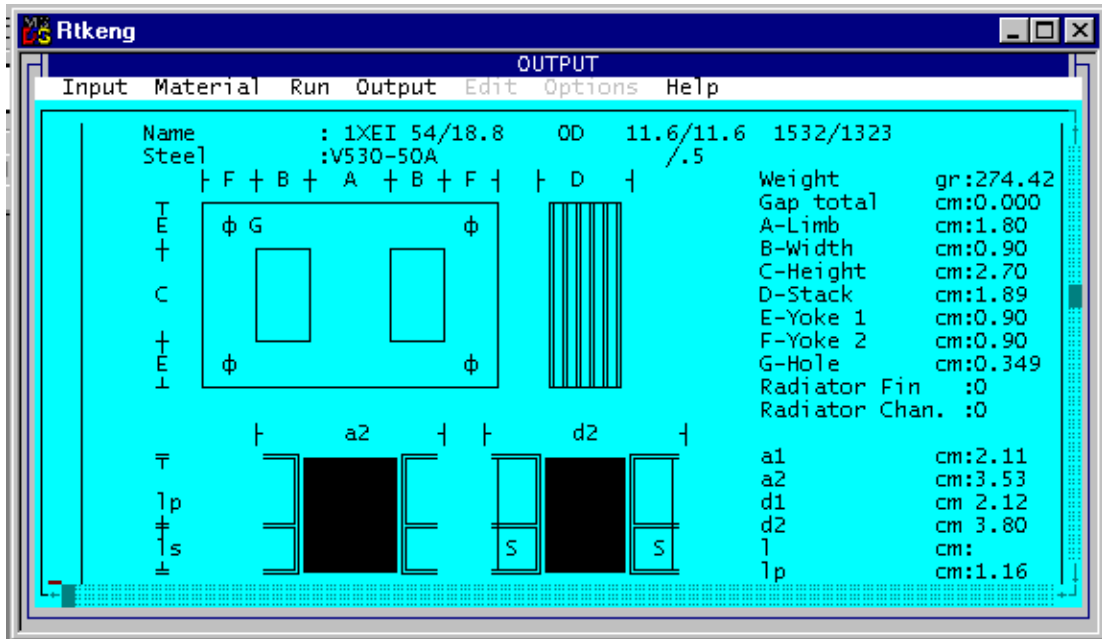
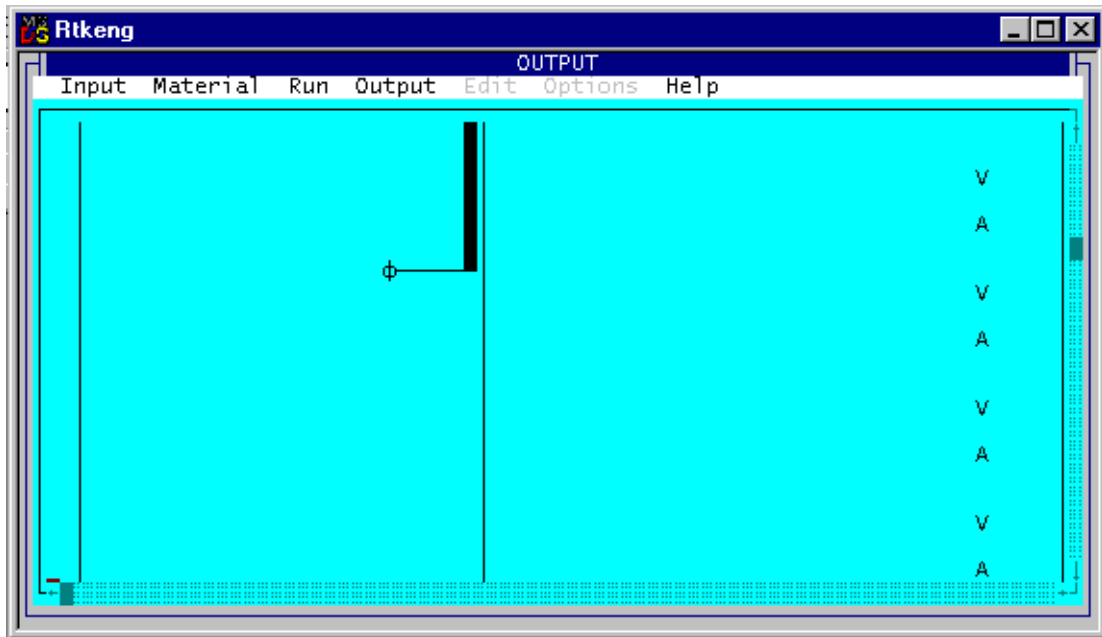
10. Start your design work. The core is selected automatically from your prescribed core family, and the program offers you a core, which is sized adequately for your application. Click on OK in order to accept the core.



On completion of your design work, the following design data is available and can be printed on three pages:



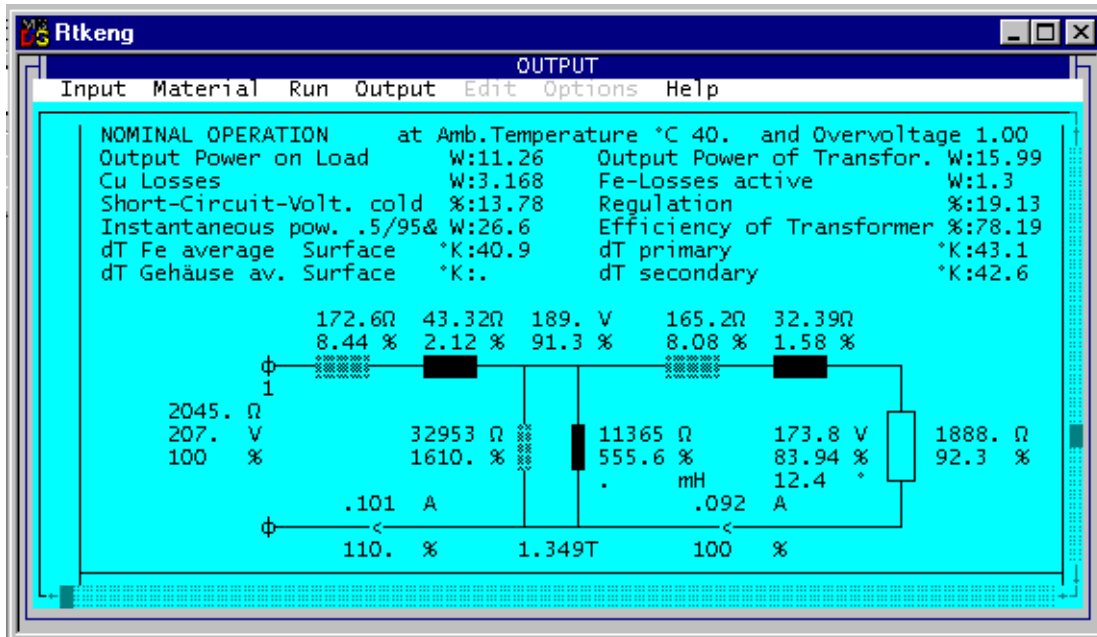


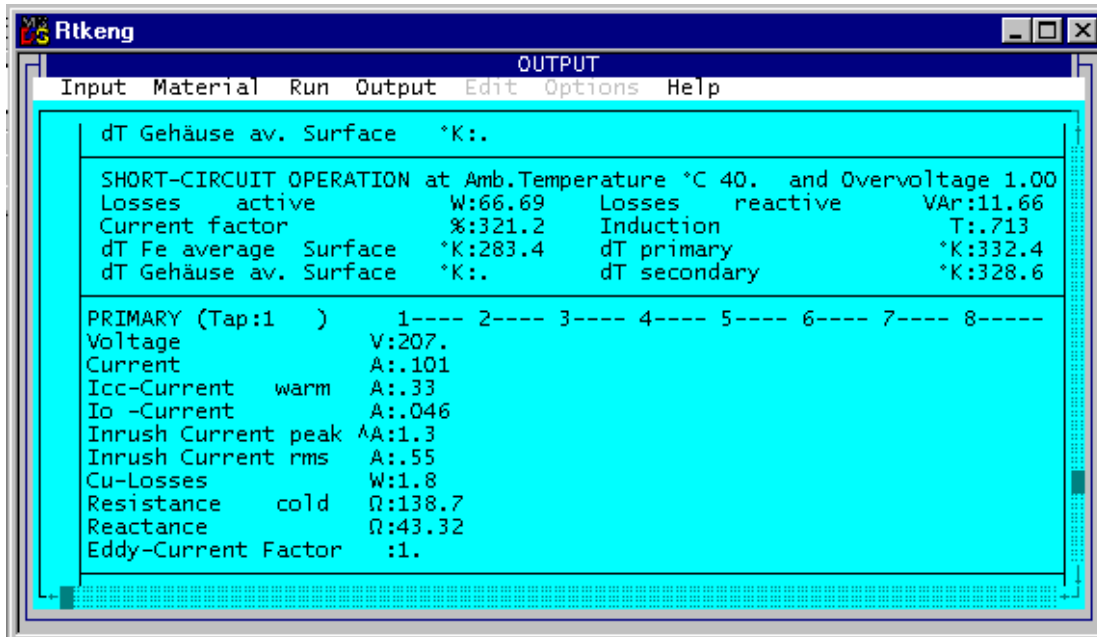
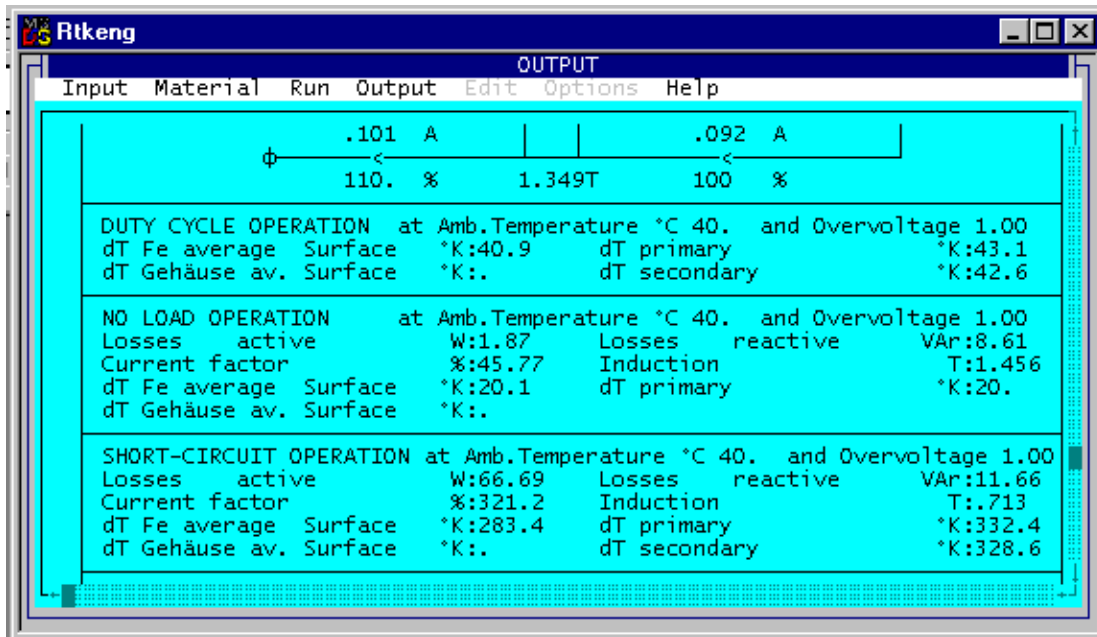


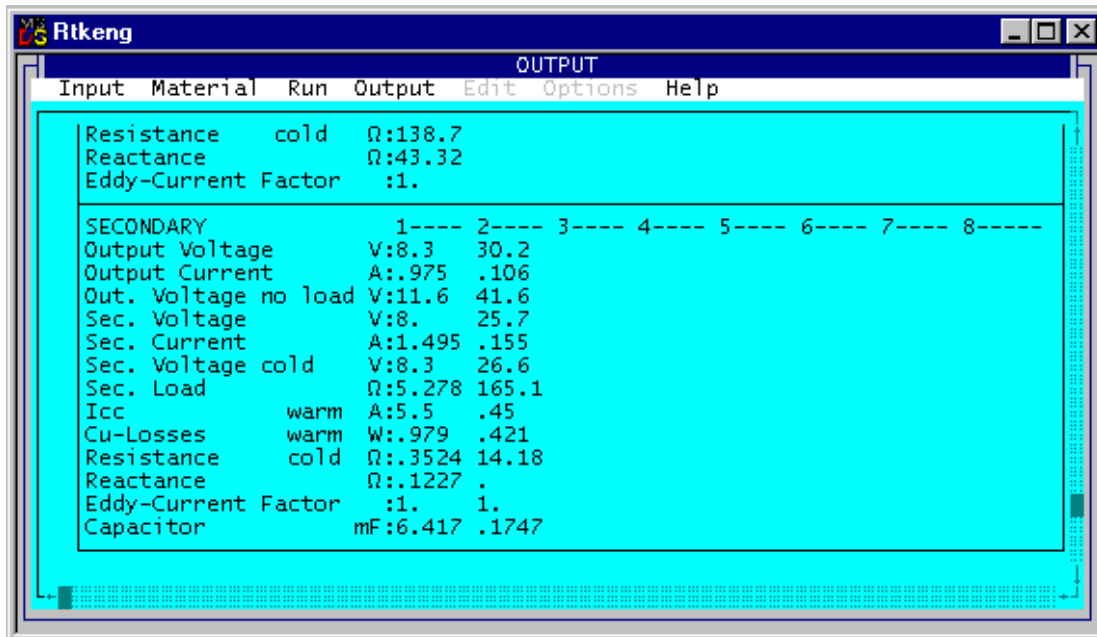
Rtkeng OUTPUT

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	1911.7	0	50.0	50.0	1	.18	.18	53.89	35.47	.	.	45.022	93.
2	33	88.0	0	77.0	77.0	1	.75	.75	12.97	6.78	.	100	34.464	73.
3	33	287.2	0	55.0	55.0	1	.236	.236	40.88	7.03	.	.	13.62	27.
4														
5														
6														
7														
8														

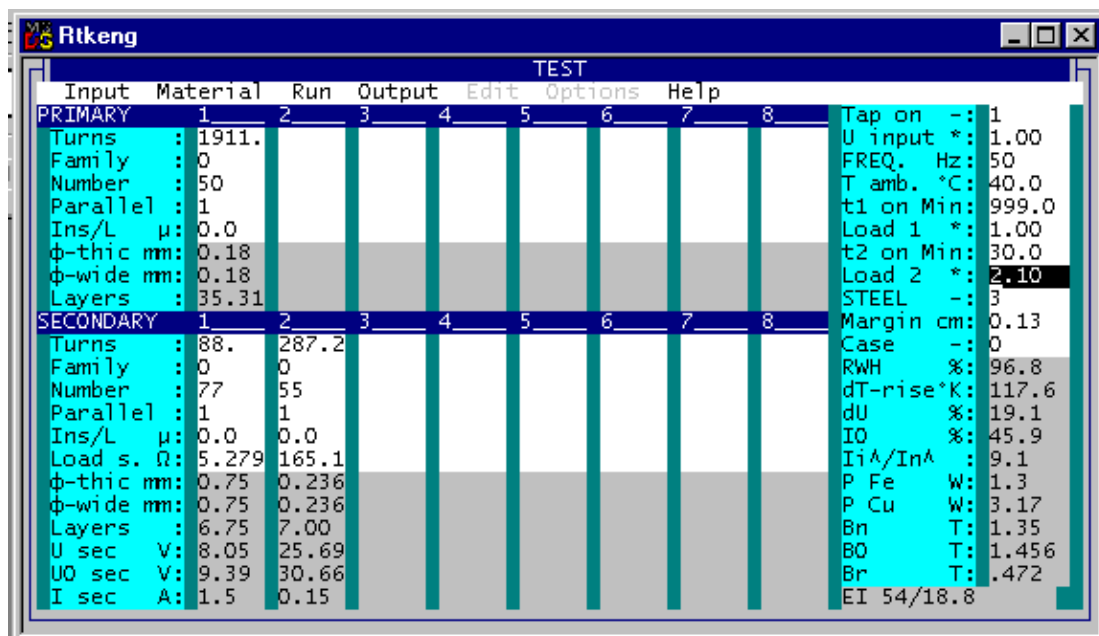






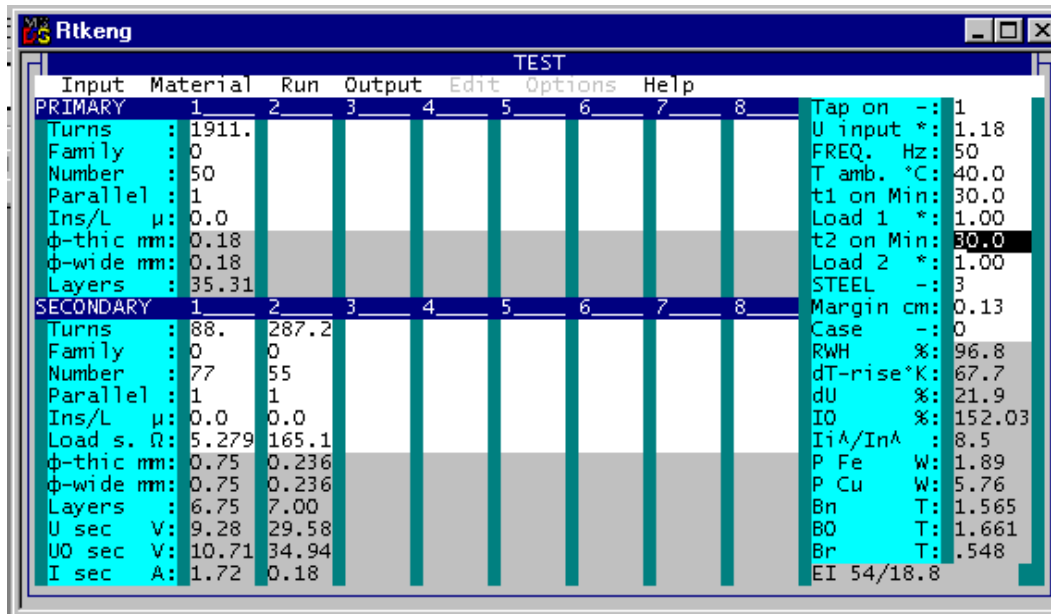
This is followed by checking of the design data.

- Firstly, we check the DC output voltages: 8.3Vdc and 30.2Vdc
- Then we check the winding data and the filling factor (96.8% < 100%).
- This is followed by the IEC 61558 test: since the voltage controller has a current limiter, the output currents of the transformer are also limited, for practical purposes: max 1.5A and 0.15A. For that reason, we select slow-blow fuses with nominal currents of 1.5A and 0.15A.

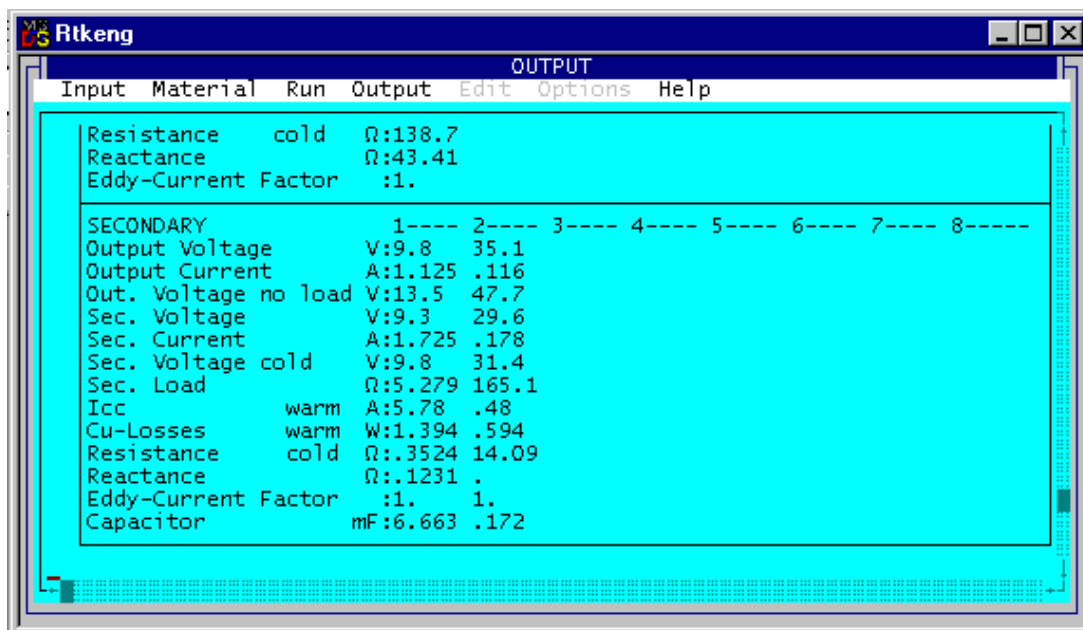


$$dT = 40 + 117.6^{\circ}\text{K} = 157.6^{\circ}\text{K} < 215^{\circ}\text{K} : \text{OK}$$

This is followed by testing at the input voltage of 243.8V:



$U_{in} = 1 * 243.8/207 = 1.18$ page of the data sheet for the winding, we should check up on the no-load output voltage: $13.5V_{dc} < 14V_{dc}$ and $47.7V_{dc} < 50V_{dc}$ is not satisfactory, then



There are two means of implementing the desired correction:

- We can either return to the input mask (function key F2), correct the input data and re-design the transformer,
- Or we can access the test program (function key F5), modify the transformer design manually and change the transformer design by that means.

On completion of our design work, we can print out the design data on-line, or save it on the local PC and print it out off-line. The output data file from this design example, CAL0005G.TK2, was supplied together with this document. Copy it into the directory in which the Rale demo program is installed.

Tips & Tricks

The temperature in the nominal operating mode is too high

- Reduce your regulation and increase your induction.
- Select a better core quality.
- Increase your cooling surface area.

Adapter

This type of transformer is very often employed in a case, not potted, as an adapter

Smoothing condenser

The program has calculated the following values for the prescribed DC voltage ripple:

$$C1 \geq 6500\mu\text{F}$$

$$C21 = C22 = 2 * 171\mu\text{F} \Rightarrow 360\mu\text{F}$$

A double-chamber transformer requires a lower capacity than a single-chamber transformer for the same output voltage ripple.

[Home](#)