

## **Semiconductor Components for Electronic Transformers**

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## Introduction

The halogen lamp, with its higher light output and what is generally described as a more pleasant light characteristic, is becoming more and more popular in both private homes and business. The typical rated voltage of these lamps (12 V) is far below the mains voltage, therefore a transformer or power supply unit is necessary when powering these lamps from the mains supply. The classic switched-mode power supply unit cannot be used, however, because it contains a secondary rectifier that would impair efficiency.

The first halogen lamps available on the market were powered by means of simple 50 Hz mains transformers. These guaranteed excellent mechanical stability of lighting fixtures, but they also dramatically increased the weight. The bulky 50 Hz transformer also posed restrictions on the design of lighting fixtures.

A reduction in the dimensions of the lighting fixtures can be achieved by using electronic transformers. Their principle is based on frequency conversion of the supply voltage. The high operating frequency involved permits the use of smaller transformer cores. Usual ferrite core transformers operate at frequencies within a range of

30 - 50 kHz. Thus, the frequency lies outside the audible range and circuits do not need to incorporate noise reduction measures.

As power output rises, electronic transformers become increasingly cheaper compared to mains transformers. They are used for powering lamp groups whenever the individual loads are not located too far apart. Designs must also deal with the emission of electromagnetic waves. These waves can cause supply cables to act as antennas, and, therefore, the length of the cables may have to be restricted.

The self-oscillating push-pull half-bridge transformer shown in figure 1 represents the circuit principle involved. If a phase control, such as the IC U2008B from TEMIC, is added to the circuit, interesting modifications will result in overload protection, soft-starting and dimmer functions.

Thanks to their switching frequency range, their high reliability and their low-cost, bipolar transistors from TEMIC in TO220 package are ideal for these applications.

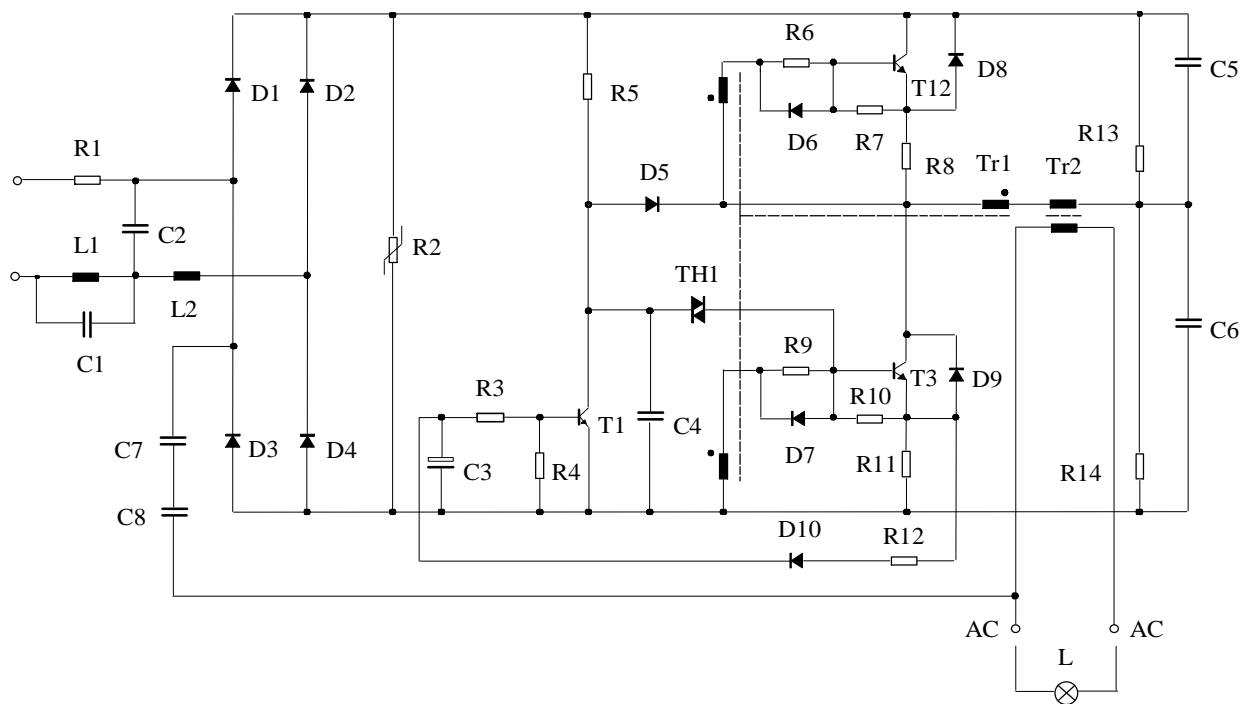


Figure 1. Standard circuit of the electronic transformer

### Description of the Standard Circuit

Figure 1 shows the typical circuit of an electronic transformer. It operates by alternately activating the transistors T2 and T3, thus generating an ac voltage in the primary winding of transformer Tr2, whose amplitude corresponds approximately to half of the mains voltage. The operating frequency is adjusted by way of feedback transformer Tr1, usually consisting of a toroidal core. The typical operating frequency range is 30 - 50 kHz.

In relation to the transformer's control response, two principles are known:

- Operation as a current transformer with deactivation after core saturation
- Operation as a voltage transformer with deactivation after the voltage has passed through zero

In the former case, the operating frequency depends on the load current, while, in the latter case, it remains almost constant. In this circuit, capacitors C5 and C6 do not serve to smooth the dc voltage, but rather serve as voltage dividers. Their capacitance values for the specified frequency range are clearly less than 1 µF. As the primary load current flows through these capacitors, they must be suitable for the expected surge currents. The load current is detected by means of emitter resistor R11 and a subsequent low pass filter. In the event of an overload, starting capacitor C4 is discharged through transistor T1. This prevents the trigger pulse, at least in the next half-wave of the mains frequency, thus relieving the power transistors and the transformer.

### Starter Circuit

During every half-wave of the mains, the lower transistor T3 is triggered by way of the RC network R5, C4 and the DIAC TH1. After triggering, the circuit continues to self-oscillate for the rest of the half-wave.

The starter circuit is very simple and functions as follows: The voltage at capacitor C4 rises in accordance with an exponential function until the trigger voltage of the DIAC TH1 is reached. The capacitor's charge then drives a current into the base of T3. The transistor is supplied immediately with base current through the trigger transformer, Tr1, and does not deactivate again until the voltage on the transformer passes through zero. During self-oscillating operation, transistor T3 periodically discharges capacitor C 4 through diode D5. During normal operation of the transformer, this prevents further triggering of the DIAC, which would lead to an inadmissible increase in dissipated power.

When no lamp load is connected to the output of the transformer, it is started periodically with the frequency

$$f_{\text{Start}} = \frac{1}{T \times \ln \left( 1 - \frac{V_{\text{Diac}}}{\sqrt{2} \times V_N} \right)} \quad (1)$$

In this case, self-oscillating mode is not possible because the control transformer, Tr1, is not carrying any noteworthy current and therefore, T3 does not remain activated.

The transformer resumes normal operation as soon as a lamp is connected to the output.

In contrast with the conventional 50 Hz transformer, the electronic transformer saves energy during no load operation.

### Balancing Measures

In the description above, it was assumed that the ON-times of the power transistors, T2 and T3, were the same. In actual practice, ON-time imbalances occur as a result of the spread of components in the control circuits and the storage times of the power transistors. These imbalances may produce a dc portion at the main transformer, Tr2. This leads to electromagnetic losses in the transformer. Storage time differences between the power transistors are the main cause of these imbalances.

TEMIC has many years of experience working with electronic ballasts for fluorescent lamps, where difficulties in storage times also influence the power output.

The dynamic characteristics of the bipolar power transistors are influenced by the dc-current gain, the blocking voltage, the technology and by the chip size. Other parameters, such as the working point and the switch-off conditions, depend on the application given by the manufacturer of the electronic transformer.

In conclusion, there are two main problems to be solved:

1. Storage time differences between the bipolar power transistors in the application must be as small as possible.
2. The absolute value of the storage time of the bipolar power transistor in the application must be appropriate for the application.

If these custom-oriented conditions are met, imbalances will be limited at acceptable levels. To help solving the problem, TEMIC provides a switching parameter, called  $t_x$ , which allows the designer to select the proper combination of bipolar power transistors. This parameter is

controlled and measured in production for 100% accuracy. From what has been stated above, it is obvious that the ability to easily make the desired groupings of bipolar transistors provides a considerable advantage when designing electronic transformers.

Figure 2 shows the grouping principle.

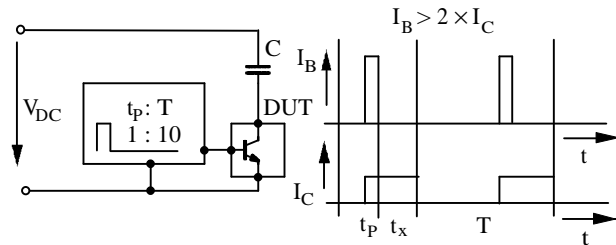


Figure 2. Grouping principle

The trigger circuit operates the transistor under test DUT with a defined pulse width and frequency. Differences in storage time or current gain produce different ON-times of the test objects. The average voltage on capacitor C, which represents the actual result of the measurement, changes to an equal extent. The relationship between the measurement process and the physical events taking place in the transistor is given by the simple equation:

$$Q = C \times V \quad (2)$$

where Q represents the charge state or overdriving of the transistor under the operating conditions of the test. With the aid of a correlation shown in figure 3, the relationship to the requirements of the final customer circuit can finally be established.

The diagram in figure 3 serves merely as an example. The y-axis may fundamentally contain all parameters relevant to the final customer circuit. Thus, by means of a standard measurement process, TEMIC is able to fulfill each individual customer requirement with suitable grouped switching transistors.

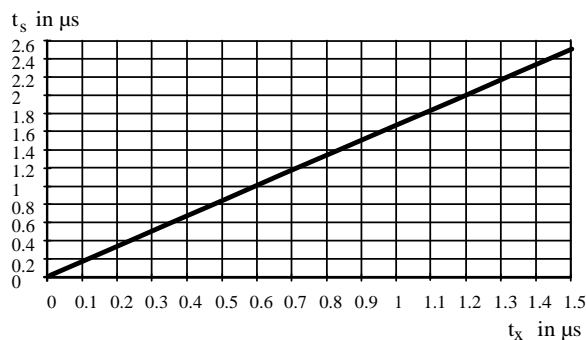


Figure 3. Correlation curve

## Overload Protection

The electronic transformer must be protected against overload because the power semiconductors and transformer Tr2 can only be loaded up to a maximum output power. Protection is achieved by measuring the emitter current of T3 by way of the voltage drop through R11 and, when the maximum current is exceeded, by shorting the starting capacitor, C4. The resistance of the halogen lamp (which is represented as a PTC resistor) is very low when it is off, thus rendering the electronic transformer's overload protection function active each time the lamp is switched on. If the control signal is applied to T1 without delay, the overload protection function would be ineffective because only a relatively low current flows during starting in every half-wave of the mains and is not interpreted as an overload. After starting, the electronic transformer containing the circuit shown in figure 1 can no longer be deactivated. The low pass filter R12/ C3 delays the build-up of voltage at the base of T1 and stores the overload information until the next half-wave of the mains. Therefore, in the event of an overload, the starting cycle can be prevented for a few half-waves of the mains, thus relieving the semiconductors and the transformer.

An excess current corresponding to eight times the nominal current may, theoretically, occur when activating halogen lamps. Therefore, no creeping overloads can be limited with the overload protection circuit shown. However, to some extent this problem can be solved satisfactorily with a deactivation facility that respond when the maximum permissible operating temperature is exceeded. This circuit variant is not shown in figure 1.

## Short Circuit Protection

The electronic transformer cannot be protected against a direct terminal short circuit of the secondary winding when using the circuit components described in the previous sub-chapter. For this event, the transformer must be switched off immediately and permanently.

As shown in figure 4, both short circuit and overload protection can be obtained with the emitter resistor of T3. The most straight forward method of activating permanent switch-off is with a thyristor that is triggered by the voltage drop through the emitter resistor R11. A feed voltage is needed to maintain the thyristor's anode current. In the standard circuit described up to now, a high-blocking capability, low-power thyristor is used for this purpose. A low-blocking capability type or a two-transistor equivalent circuit can be used in the circuits with a dimming function, which will be discussed in detail further below.

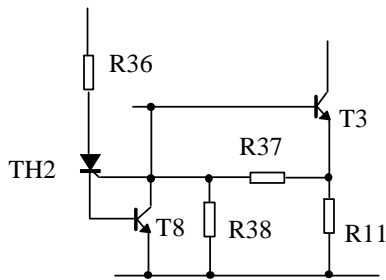


Figure 4. Short circuit deactivation

### Working Voltage

In electronic transformers for halogen lamps, the bipolar transistors are blocked by either short circuit respectively resistance  $< 100 \Omega$  between base and emitter or negative base emitter voltage, but not with base emitter open circuit.

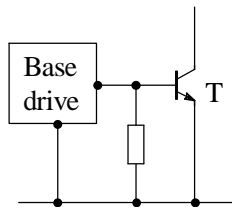


Figure 5. Base emitter resistance

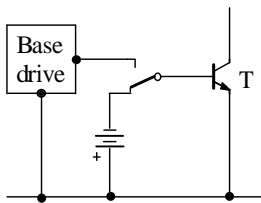


Figure 6. Negative base emitter voltage

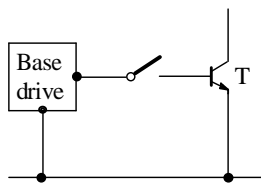


Figure 7. Base emitter open circuit

So it must be emphasized that the value of  $V_{CE0}$  is not the correct parameter to determine the switching capability of a bipolar power transistor. TEMIC defines the switching capability of a bipolar power transistors as:

$$V_{CEW}$$

the so-called working voltage. This  $V_{CEW}$  is the maximum voltage at which a TEMIC bipolar power transistor can be switched on and off without any risk at a

maximum collector current under defined base drive conditions.

This results in a collector current versus working voltage area which is also known as the RBSOA (**R**everse **B**iased **S**afe **O**perating **A**rea) or FBSOA (**F**orward **B**iased **S**afe **O**perating **A**rea) diagram of a bipolar transistor. TEMIC combines these as SWA (**S**afe **W**orking **A**rea).

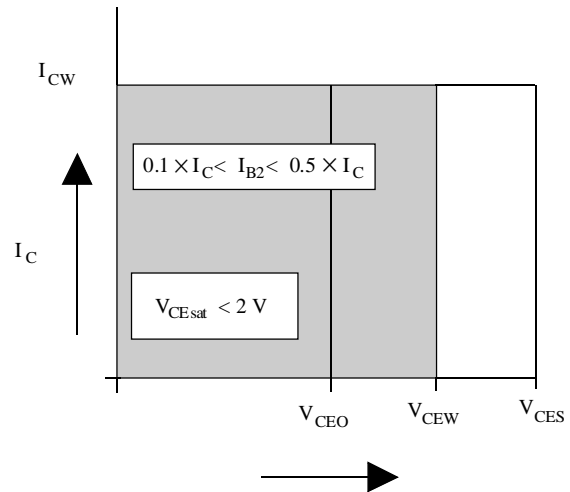


Figure 8. Safe Working Area

The values of  $I_{CW}$ ,  $V_{CEW}$ ,  $V_{CE0}$  and  $V_{CES}$ , shown in figure 8, depend on the type of transistor.

The highest working voltages will be achieved if the reverse base current ( $I_{B2}$ ) is greater than 10% and less than 50% of the collector current. For the forward base current, it is assumed that the transistor should be saturated at the collector current so that  $V_{CEsat} < 2 \text{ V}$  is guaranteed.

The hatched area shown in figure 8 indicates Safe Working Area for TEMIC transistors.

### Transistor Selection

Selection must be based on the following criteria:

- Amount of mains voltage ( $V_{CES} > 700 \text{ V}$  at  $V_N = 230 \text{ V}$ )
- Nominal power ( $I_C$ )
- Overcurrent when lamps switching on
- Overvoltage when circuit is working ( $V_{CEW}$ )
- Nature of the circuit (half-, full-bridge, dimmed or undimmed)

Extremely low losses in power transistors enable operation with a small heat sink or, under certain conditions, even without any at all. Switching and saturation losses

can generally be looked upon as representing substantial losses. The high-speed- or SWOT technology employed in TEMIC transistors produces minimum switching losses. To guarantee minimum saturation losses, the transistor's dc current gain at the maximum expected collector current in the application and 2 V saturation voltage should be higher than 5.

Tables 1 and 2 are based on the following considerations:

Given the main voltage  $V_N$ , the rms value of the main transformer's primary voltage in the case of a half-bridge circuit amounts just to  $0.5 V \times V_N$ . The following equitation then approximates the voltage or current transformation ratio:

$$\frac{w_P}{w_S} = \frac{V_N}{2 \times V_H} \quad (3)$$

In the case of the full-bridge circuit, the full rms value of the mains voltage is applied to the primary winding of the main transformer and the following applies accordingly:

$$\frac{w_P}{w_S} = \frac{V_N}{V_H} \quad (4)$$

where:

- $w_P$  number of primary turns
- $w_S$  number of secondary turns
- $V_N$  rms value of mains voltage
- $V_H$  nominal voltage of the halogen lamp

In the tables 2 and 3, the halogen lamp is assumed to have a nominal voltage of 12 V. The lamp's nominal operating currents can be calculated by way of the nominal power,  $P_H$ :

$$I_{\text{eff}} = \frac{P_H}{V_H} \quad (5)$$

The primary rms currents, and thus also the peak values of these currents, can be calculated with the transformation ratios from equations (3) and (4). The overload factor defines the highest possible peak collector currents with which the transistors are loaded during activation. Definition of this value always represents a compromise between the fastest possible activation (with a high load for the lamps and transistors) and slow activation (with a corresponding ON-delay). A practical overload factor of 2.7 is assumed in both tables.

Table 1. Transistors for 230 V mains

Power at 230 V in W	Half-Bridge Circuit				Full-Bridge Circuit			
	Standard		With Soft Start		Standard		With Soft Start	
	$\hat{I}$ in A	Type	$\hat{I}$ in A	Type	$\hat{I}$ in A	Type	$\hat{I}$ in A	Type
35	1.14	BUD620 TD13005D	0.57	BUD600	0.57	BUD600	0.29	BUD600
50	1.7	BUF644	0.85	BUF620 TD13005D	0.85	BUF620 TD13005D	0.42	BUD600
75	2.5	BUF650	1.25	BUF630 BUF636A	1.25	BUF630 BUF636A	0.63	BUD620
105	3.5	BUF654	1.75	BUF644	1.75	BUF644	0.88	BUF620 TE13005D
150	5.0	TE13009	2.5	BUF650	2.5	BUF650	1.25	BUF630 BUF636A
200	6.7	---	3.35	BUF654	3.35	BUF654	1.68	BUF644
400	13.4	---	6.7	---	6.7	---	3.35	TE13009

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Table 2. Transistors for 120 V mains

Power at 120 V in W	Half-Bridge Circuit				Full-Bridge Circuit			
	Standard		With Soft Start		Standard		With Soft Start	
	$\hat{I}$ in A	Type	$\hat{I}$ in A	Type	$\hat{I}$ in A	Type	$\hat{I}$ in A	Type
35	2.3	BUF650	1.14	BUF630 TD13005D	1.14	BUF630 TD13005D	0.57	BUD600
50	3.4	BUF654	1.7	BUF644	1.7	BUF644	0.85	BUF620 TD13005D
75	5.0	TE13009	2.5	BUF650	2.5	BUF650	1.25	BUF630
105	7.0	---	3.5	BUF654	3.5	BUF654	1.75	BUF644
150	10.0	---	5.0	TE13009	5.0	TE13009	2.5	BUF650
200	13.4	---	6.7	---	6.7	---	3.35	BUF654

The TE13005D includes an integrated, antiparallel, free-wheeling diode which, as has been shown, is absolutely necessary for all electronic transformers. The user is thus given two advantages:

- Lower cost in comparison with two discrete components
- Lower component complexity

The two tables show the influence of the circuit type on the choice of transistors. While using the same transistor type, the circuits with soft starting are suitable for twice the power output of the standard circuit.

On the other hand, the influence of the magnitude of the mains voltage becomes evident too. Halving the mains voltage results in half the power output despite use of the same power transistor.

For example, to use the transistors in the low-cost TO 220 package with 120 V mains, the full-bridge circuit must already be used at powers in excess of 105 W. The tables also show that full-bridge circuits equipped with soft starting allow power outputs of up to 400 W with one transformer, thus enabling comfortable illumination of large rooms (e.g. business rooms).



## Dimmable Electronic Transformer with U2008B

A conventional TRIAC dimmer as has been known for some time in relation to brightness control of incandescent bulbs can be used to control electronic transformers or the brightness of connected halogen lamps (dimming). As an additional unit, however, such a dimmer increases costs substantially while bringing with it an undesirable increase in size.

These disadvantages can be obviated by exploiting special operating characteristics of the electronic transformer, which almost call for the use of an integrated phase control. The smoothing capacitors in the transformer's intermediate dc voltage circuit have very low capacitance values, among other things, to minimize the amount of filtering required for the mains current. The result is that self-oscillating operation of the transformer is interrupted at the end of each half-wave of the mains or has to be restarted during each half-wave. From the point of view of circuit configuration, this corresponds to the control response of a TRIAC on the mains.

Using the integrated circuit U2008B, the transformer can be started at almost any time during a half-wave of the mains. The unit also provides other advantages. A

soft-starting response during activation, for instance, allows higher continuous outputs with the same power transistor to be achieved and increases the lamp's lifetime. The overload protection function, which limits the output power, prevents a continuous overload as is possible in the standard circuit. Thus, the circuit is protected effectively even in the event that the wrong lamp is used. This circuit does not require an additional power TRIAC.

The U2008B is a classical phase control IC. In this circuit, the trigger pulse (Pin 8) with which a TRIAC is otherwise triggered, serves as a starting pulse via T1 for the half-bridge transformer. The trigger pulse position within the half-wave of the mains or the control angle,  $\alpha$ , defines the amount of the output voltage, as is known from the classical phase control principle.

By means of a high-resistance voltage divider (R8, R9, R10 at Pin 3), the phase angle  $\alpha$ , and thus the output voltage at the lamps, can be controlled almost powerlessly. Simple remote control of individual lamps or groups of lamps through infrared or RF transmission links, which can also be designed as multiplexed

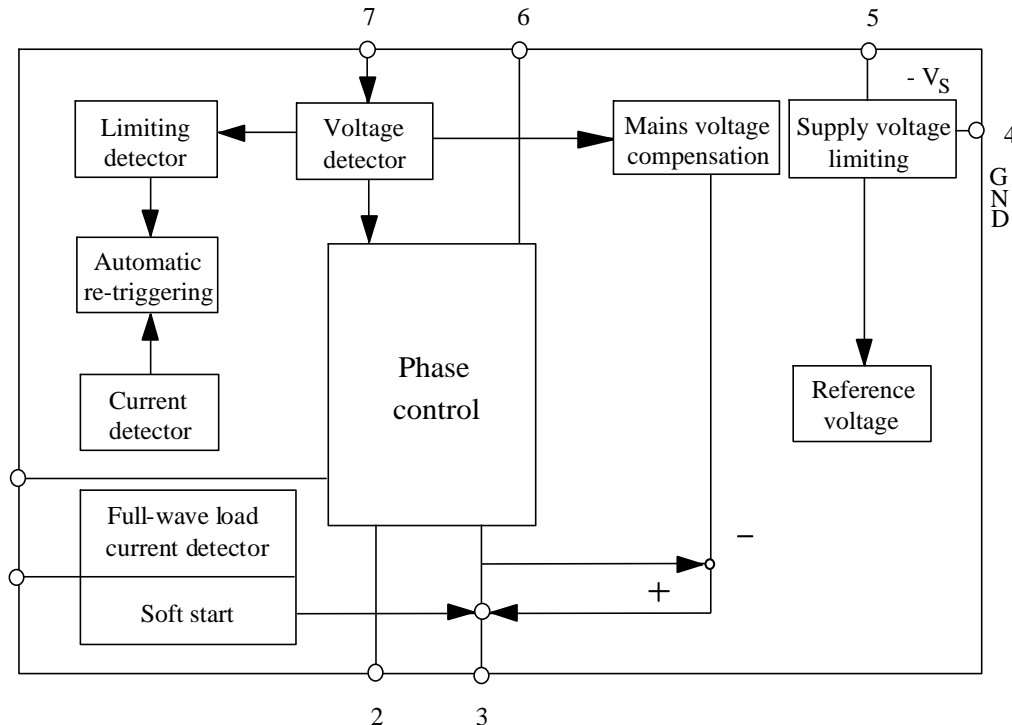


Figure 9. Block diagram of the U2008B

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systems, is therefore possible. Thus in certain circumstances, wiring problems are easily handled when adding lamps to the system at a later time. The system is open for control through a "insta bus" and is therefore oriented to the future. At the same time, the component requirements for the circuit shown in figure 10 (the actual transformer circuit) are also reduced.

### Simple Controller

The simple controller circuit can be done in one of a number of versions depending on the convenience required. Soft starting, which enables gentle activation of the lamps, is one additional advantage of this circuit. The U2008B in a DIP 8 or SO 8 package is suitable for use as a low-cost control component. Special characteristics of the U2008B include:

- Mains voltage compensation (Pin 7)  
As the mains voltage increases, the control angle is enlarged and the output voltage is reduced. The compensation effect is variable.
- Soft start function (Pin 2)  
The voltage at Pin 1 defines the minimum control angle. The value of the capacitor C4 determines the soft-start response. In the event of an overload, the transistor T2 produces an enlargement of the control angle or a reduction of the output voltage, thus providing overload protection.

- Mains voltage synchronization (Pin 7)  
The control angle  $\alpha = 0^\circ$  is defined. The diode D7 is needed to ensure that the U2008B can be synchronized to the points where the mains voltage passes through zero.
- Current consumption less than 3 mA

Figures 11 and 12 show the oscillograms of the transformer's mains current consumption at a minimum control angle or maximum output power and at  $\alpha \approx 90^\circ$  or half the output voltage. The almost sinusoidal mains current consumptions achieved with relatively simple input filters are apparent.

This circuit enables continuous adjustment of the lamp voltage to between 0 and 100% of the nominal voltage. It is set by means of the external potentiometer, R9. The maximum control angle,  $\alpha_{max}$ , and thus the minimum output voltage, are set with the trimmer R5. Fixed resistors R8 and R10 limit the customer's specific adjustment range for phase control.

Note that the control angle must not fall below a specific minimum in this circuit (i.e. for inadequate values of the mains voltage), otherwise the conditions for self-oscillation of the transformer are no longer met. This effect manifests itself by flickering or complete extinguishing of the lamps at the potentiometer's full load setting.

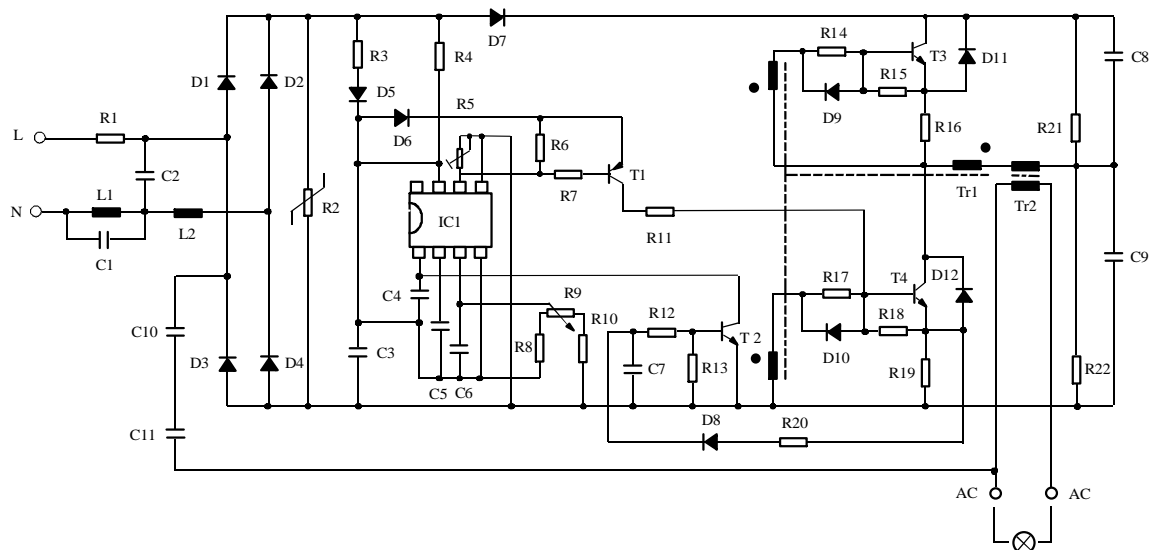
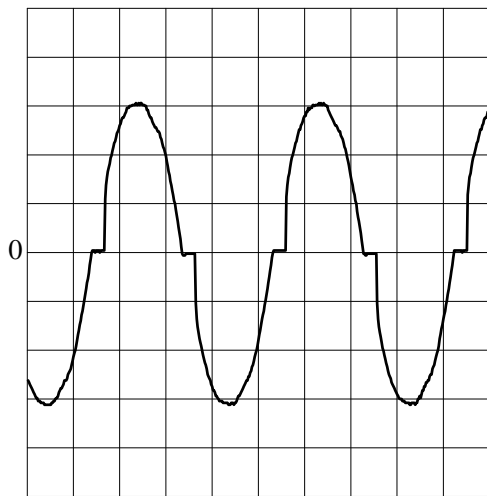
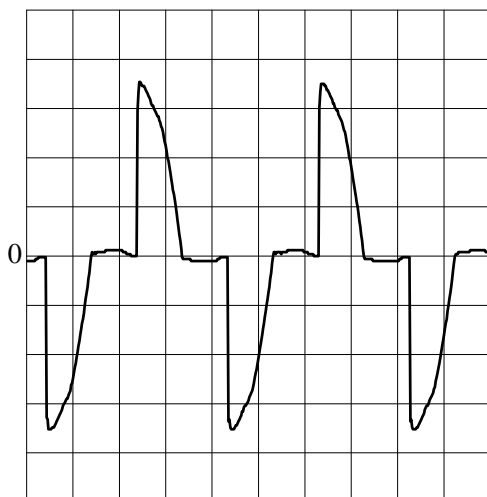


Figure 10. Dimmable electronic transformer for halogen lamps



$I_N : 0.2 \text{ A/div}$  Time base : 5 ms/div

Figure 11. Mains current consumption at full load



$I_N : 0.2 \text{ A/div}$  Time base : 5 ms/div

Figure 12. Mains current consumption at half full load

## Transformer with Slaved Output Voltage

In the case of both 50 Hz transformers and electronic transformers, fluctuations in the mains voltage produce fluctuations in the output voltage. Particularly in the event of excess voltages, these fluctuations may result in an overloading of the connected halogen lamps. The voltage increase at low lamp load is a further undesirable effect.

By means of phase control, slaving of the output voltage by the phase control angle will prevent such operating situations.

First, the output voltage must be measured and transferred to the primary side.

When employing peak value rectification, the peak value of the output voltage is usually available as a measured value. The lamps are supplied with the rms value, which is not comparable with the dc peak voltage. Therefore, it is not an exact loop control but a delay control.

In the circuit shown in figure 13, the output voltage is measured directly by way of full wave peak value rectification. The threshold value for the response of T7 or OK1 can be set by means of voltage dividers R31, R32 and R33. In this case, R32 is the setting potentiometer. The coupler's output transistor influences voltage dividers R23, R24, R25 + R9 and thus the input voltage at Pin 3 of the U2008B. The control range can be set by means of the trimmer R9. With this function, all lamps connected to one single transformer can be activated or deactivated individually. Using an uncontrolled transformer would overload the connected lamps if the transformer were underloaded.

The circuit shown in figure 13 offers overvoltage deactivation via the components D13, D14, T5, T6, R26, R27, R28, R29, C13 as an additional protective function. When the Zener diode D14 responds, starting pulses from T1 are shorted via T5 and soft starting after reduction of the mains voltage is prepared via T6.

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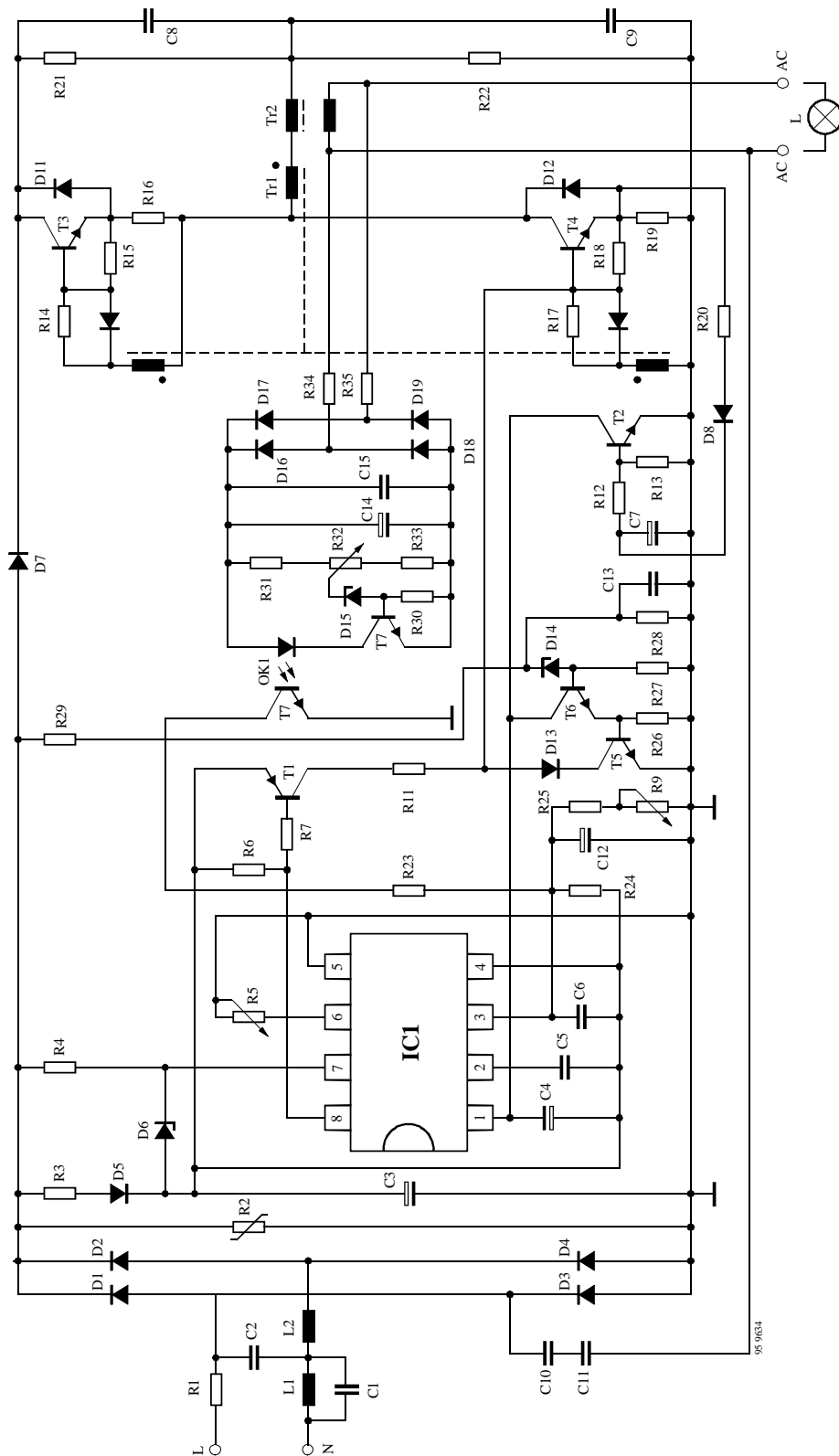


Figure 13. Dimmable electronic transformer with slaved output voltage

## Full-Bridge Circuit for Higher Powers

The standard circuit in figure 1 uses only half the value of the mains voltage as the input voltage of the transformer. This is why, in devices with relatively low power, high primary currents already flow and place a burden on the transistors. In the case of applications involving the same power in connection with the 120 V mains, the currents are doubled yet again.

Therefore, a circuit that enables the full mains voltage on the primary winding is suitable for higher-power applications on the 230 V mains and in the case of 120 V devices. The full-bridge circuit is achieved by replacing the capacitors C8 and C9 in the standard circuit and by switching transistors and free-wheeling diodes.

Transistors T5 and T6 are triggered in the same way as T3 and T4 via the toroidal core, Tr1, which contains two additional control windings.

It is not possible to make a general statement as to which circuit configuration is better in a practical circuit. If a higher-power lighting facility is required, it is best to use only one transformer for 400 W in a full-bridge circuit (4 x BUF654 + U2008B) rather than four transformers with 100 W in a half-bridge circuit (8 x BUF644).

The differences in terms of dimensioning between the full-bridge circuit and the standard circuit is discussed below.

In comparison with the standard circuit, activation of only one of the four power transistors in this circuit does not produce a flow of current through the main transformer.

Therefore, the trigger pulse must be fed through the trigger transformer to two transformer each of one bridge diagonal in order for the transformer to start oscillating. This is why a higher pulse power is needed for reliable oscillation.

Owing to the magnetizing reactive power, even in this circuit, an intermediate circuit capacitor, no matter how small, must be used.

One problem that might occur in units with a maximum power output is the influence of the transformer's leakage inductance on the shape of the current. Up to now,

considerations have always been based on an almost rectangular lamp current whose amplitude is modulated with the momentary values of the mains voltage. In actual fact, however, the lamp current is delayed by the time constant  $\tau$ :

$$\tau = \frac{L_{\sigma}}{R_{\text{lamp}}} \quad (6)$$

Assuming an operating frequency of 40 kHz corresponding to a period of 25  $\mu\text{s}$  and a maximum permissible time constant  $\tau = 2.5 \mu\text{s}$ , for example, we arrive at the following leakage inductance limits:

P in W	R <sub>lamp</sub> in $\Omega$	L <sub><math>\sigma</math></sub> limit in nH
50	2.88	7200
100	1.44	3600
200	0.72	1800
400	0.36	900
800	0.18	450

An excessive leakage inductance value itself does not increase losses. Instead, it reduces the form factor for the lamp current. In simplified terms, this means that the peak currents have to be increased accordingly by modifying the turn ratio in order to reach the rms value or the nominal power output. This leads to an increase in losses in the transformer and also on the power transistors. It is possible to avoid this effect by means of special winding techniques, for example, but these are not discussed in further detail here.

When dimensioning very high power circuits (e.g., of a 400 W transformer as described in chapter 'Full-Bridge Transformer for 230 V/ 400 V'), it may be expedient to reduce the operating frequency in order to reduce the influence of leakage inductance on the one hand and to limit switching losses of the power transistors on the other hand. The example circuit operates with approximately 25 kHz at nominal load. At this power, it is absolutely necessary to cool the power transistors. A heat sink with a thermal resistance of 5 K/W is advisable

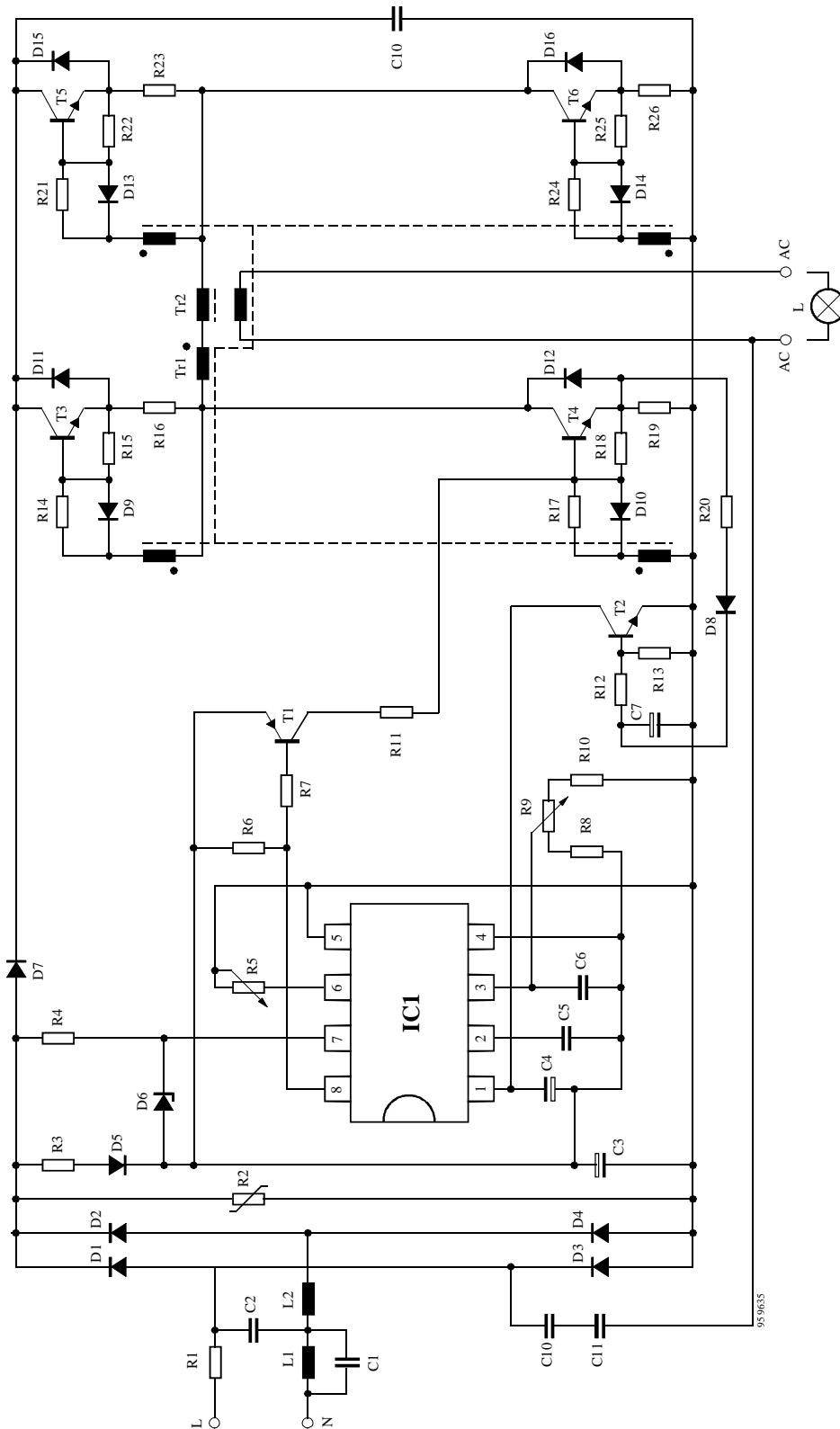


Figure 14. Dimmable electronic transformer as a full-bridge transformer for halogen lamps.

## Circuit Examples

### Standard Circuit for 230 V/ 100 W

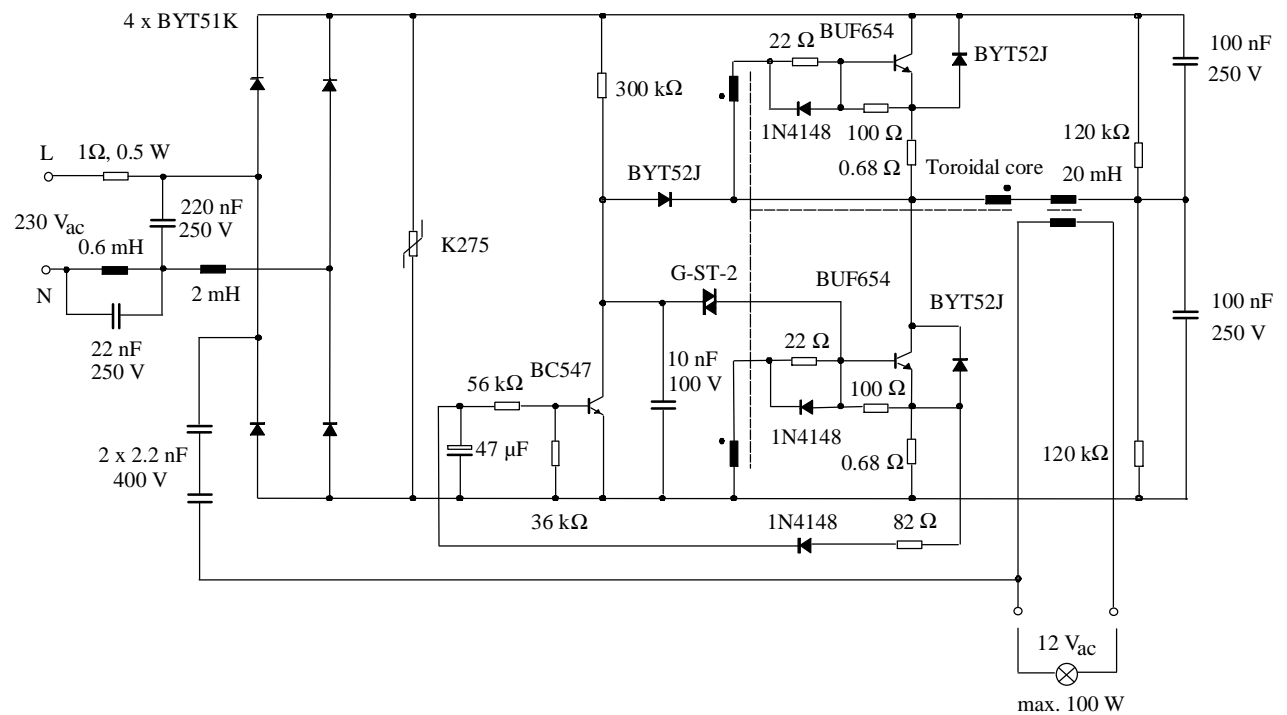


Figure 15. Electronic transformer, 100 W

### Characteristics:

- Simple circuit
- Low volume
- Low weight
- High efficiency
- Minimum idling losses
- 100 W power output

### Typical Applications:

- Simple halogen lighting fixtures fitted with 12 V/100 W lamps
- Possibly dimmed externally

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### Voltage Controller with U2008B for 230 V/ 100 W

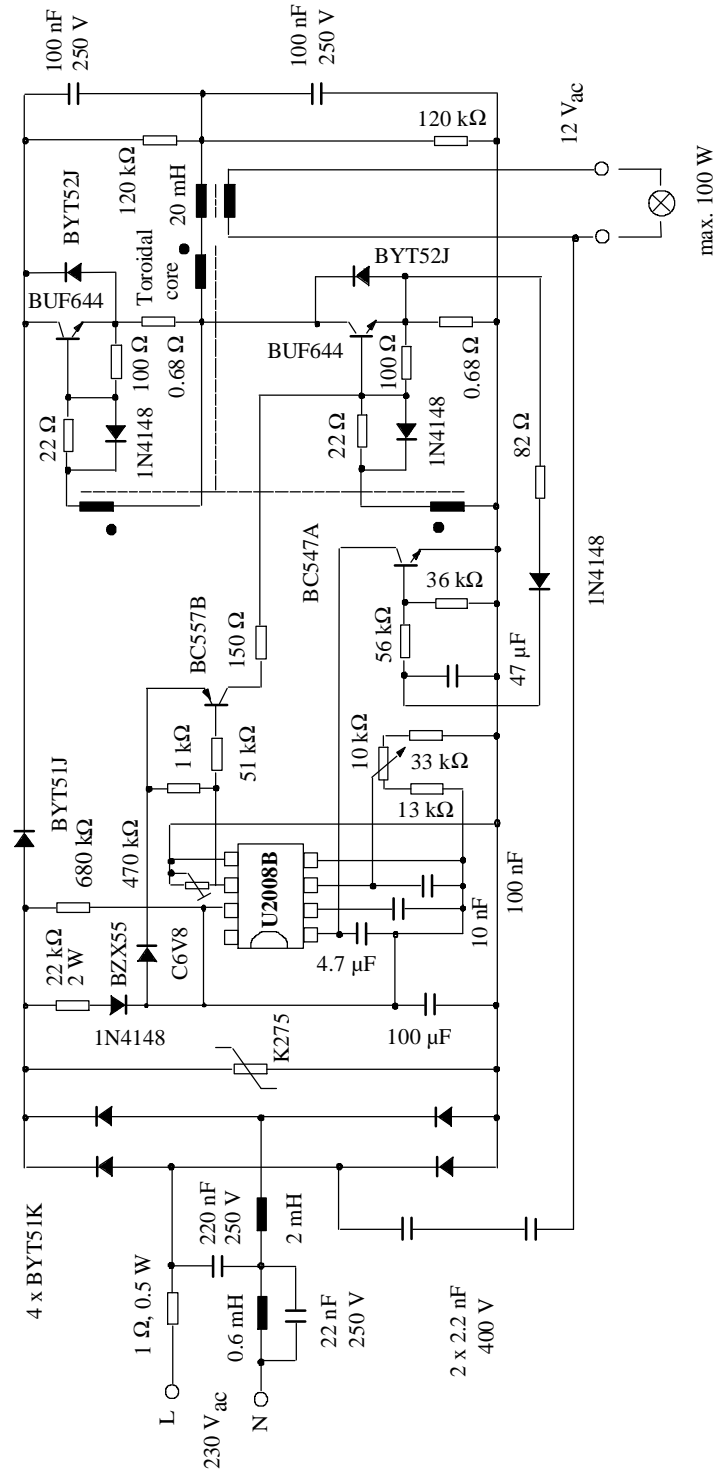


Figure 16. 100 W half-bridge transformer with soft start



## Characteristics:

- Simple circuit
- Low volume
- Low weight
- High efficiency
- Minimum idling losses
- Dimmable without the need of additional components
- Overload-protected
- 100 W power output

## Typical Applications:

- Dimmable halogen fixtures that can be fitted with 12 V lamps (25 - 100 W)
- Possibility of activating or deactivating the lamps during operation

## Dimmable Transformer with Slaved Output Voltage

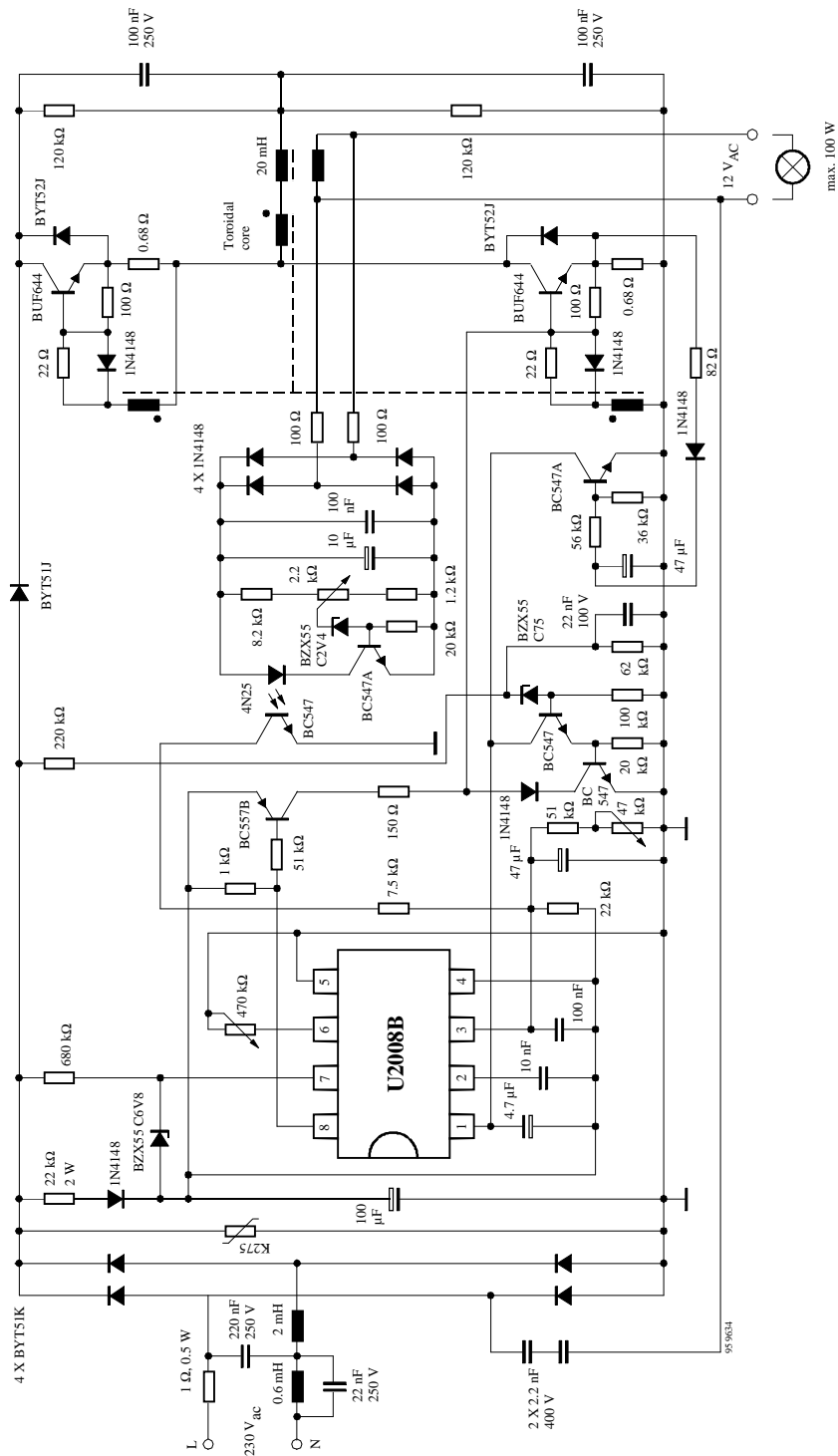


Figure 17. Dimmable electronic transformer (100 W) with slaved output voltage

## Characteristics:

- Low weight
- Low volume
- High efficiency
- Minimum idling losses
- Dimmable without the need of additional components
- Mains voltage compensation
- Overload protected
- 100 W power output

## Typical Applications:

- Dimmable halogen lighting fixtures that can be fitted with 12 V lamps (0 W to 100 W)
- Possibility of activating or deactivating the lamps during operation (useful in the event of highly fluctuating mains voltages)

## Full-Bridge Transformer for 230 V/ 400 W

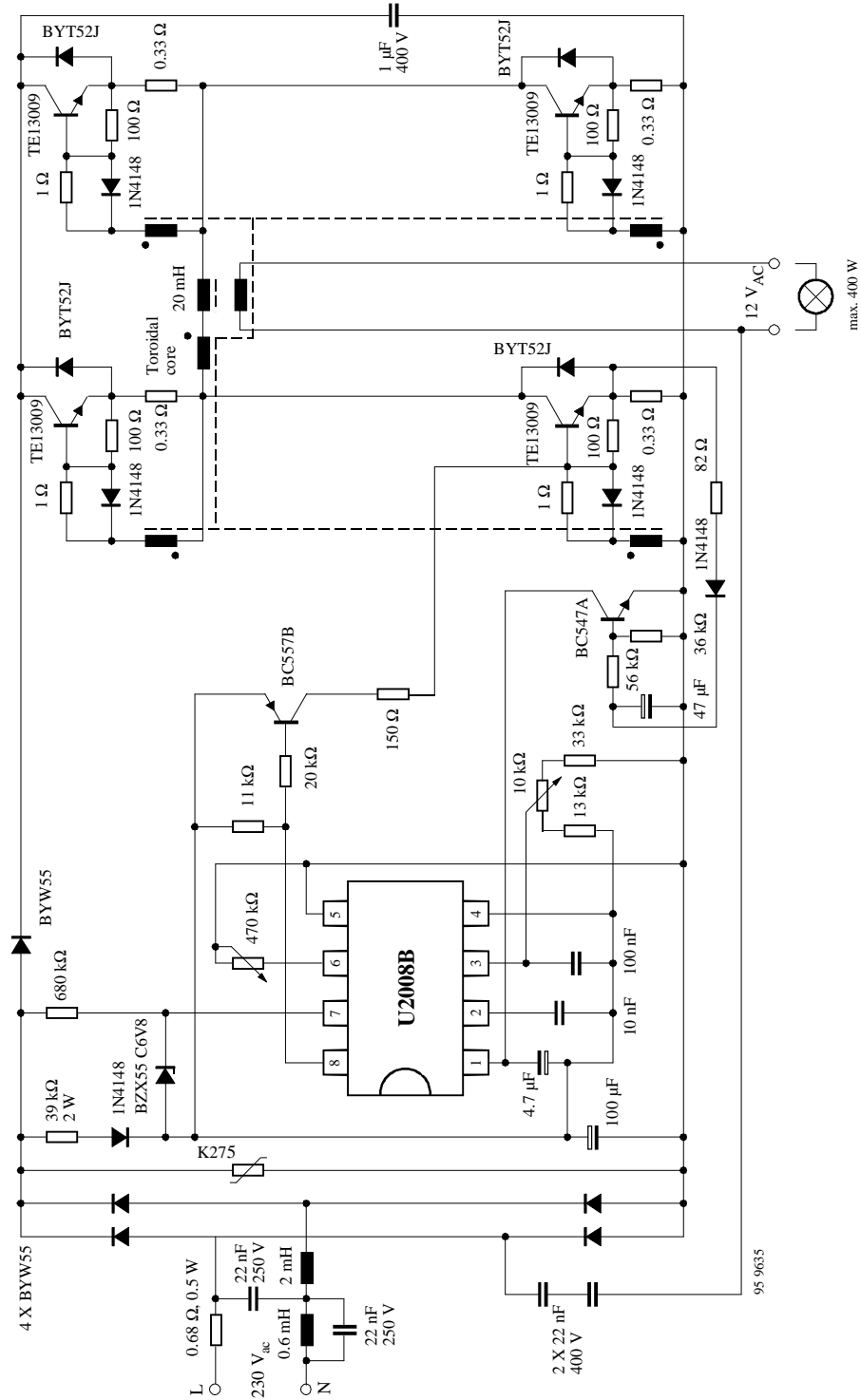


Figure 18. Full-bridge transformer, dimmable for 400 W

## Characteristics:

- Simple circuit
- Low volume
- Low weight
- High efficiency
- Minimum idling losses
- Dimmable without the need for additional components
- Overload protected
- 400 W power output

## Typical Applications:

- Dimmable room lighting fixtures that can be fitted with 12 V lamps (100 W to 400 W)
- Possibility of activating or deactivating the lamps during operation

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### Annex

#### Parts Lists

**Standard circuit for 230 V/ 100 W as shown in figure 1**

T1	BC547	
T2	TE13009	
T3	TE13009	
D1	BYT51K	
D2	BYT51K	
D3	BYT51K	
D4	BYT51K	
D5	BYT52J	
D6	1N4148	
D7	1N4148	
D8	BYT52J	
D9	BYT52 J	
D10	1N4148	
R1	1 $\Omega$	0.5 W
R2	K275	Varistor
R3	56 k $\Omega$	
R4	36 k $\Omega$	
R5	300 k $\Omega$	
R6	22 $\Omega$	
R7	100 $\Omega$	
R8	0.68 $\Omega$	
R9	22 $\Omega$	
R10	100 $\Omega$	
R11	0.68 $\Omega$	
R12	82 $\Omega$	
R13	120 k $\Omega$	
R14	120 k $\Omega$	
C1	22 nF	250 V
C2	220 nF	250 V
C3	47 $\mu$ F	6.3 V
C4	10 nF	100 V

C5	100 nF 250 V
C6	100 nF 250 V
L1	0.6 mH E 13/4 (d = 0 mm)
L2	2 mH E 16/5 (d = 0 mm)
Tr1	Toroidal core (10 mm $\varnothing$ )
Tr2	20 mH E 32/9 (d = 0 mm)

**Voltage controller with U2008B (100 W/ 230 V) as shown in figure 10**

IC1	U2008B	
T1	BC557B	
T2	BC547	
T3	BUF644	
T4	BUF644	
D1	BYT51K	
D2	BYT51K	
D3	BYT51K	
D4	BYT51K	
D5	1N4148	
D6	BZX55C6V8	
D7	BYT51J	
D8	1N4148	
D9	1N4148	
D10	1N4148	
D11	BYT52J	
D12	BYT52J	
R1	1 $\Omega$	0.5 W
R2	K275	Varistor
R3	22 k $\Omega$	2 W
R4	680 k $\Omega$	
R5	470 k $\Omega$	Trimmer
R6	1 k $\Omega$	
R7	51 k $\Omega$	
R8	13 k $\Omega$	

R9	10 k $\Omega$		T2	BC547	
R10	33 k $\Omega$		T3	BUF644	
R11	150 $\Omega$		T4	BUF644	
R12	56 k $\Omega$		T5	BC547	
R13	36 k $\Omega$		T6	BC547	
R14	22 $\Omega$		T7	BC547	
R15	100 $\Omega$		D1	BYT51K	
R16	0.68 $\Omega$		D2	BYT51K	
R17	22 $\Omega$		D3	BYT51K	
R18	100 $\Omega$ P		D4	BYT51K	
R19	0.68 $\Omega$		D5	1N4148	
R20	82 $\Omega$		D6	BZX55C6V8	
R21	120 k $\Omega$		D7	BYT51J	
R22	120 k $\Omega$		D8	1N4148	
C1	22 nF	250 V	D9	1N4148	
C2	220 nF	250 V	D10	1N4148	
C3	100 $\mu$ F	Electrolytic capacitor	D11	BYT52J	
C4	4.7 $\mu$ F	Electrolytic capacitor	D12	BYT52J	
C5	10 nF		D13	1N4148	
C6	100 nF		D14	BZX55C75	
C7	47 $\mu$ F	16 V El. cap.	D15	BZX55C2V4	
C8	100 nF	250 V	D16	1N4148	
C9	100 nF	250 V	D17	1N4148	
C10	2.2 nF	400 V	D18	1N4148	
C11	2.2 nF	400 V	D19	1N4148	
L1	0.6 mH	E 13/4 (d = 0 mm)	R1	1 $\Omega$	0.5 W
L2	2 mH	E 16/5 (d = 0 mm)	R2	K275	Varistor
Tr1	Toroidal core	10 mm $\varnothing$	R3	22 k $\Omega$	2 W
Tr2	20 mH	E 32/9 (d = 0 mm)	R4	680 k $\Omega$	
			R5	470 k $\Omega$	Trimmer
			R6	1 k $\Omega$	
			R7	51 k $\Omega$	
			R9	47 k $\Omega$	Trimmer
			R11	150 $\Omega$	
			R12	56 k $\Omega$	
			R13	36 k $\Omega$	
<b>Dimmable transformer with slaved output voltage (230 V/100 W) as shown in figure 13</b>					
IC1	U2008B				
OK1	4N25				
T1	BC557B				

R14	22 Ω			C14	10 μF	25 V	El.cap.
R15	100 Ω			C15	100 nF		
R16	0.68 Ω			L1	0.6 mH		
R17	22 Ω			L2	2 mH		
R18	100 Ω			Tr1	Toroidal core (10 mm Ø)		
R19	0.68 Ω			Tr2	E 32/9 (d = 0 mm)		
R20	82 Ω			<b>Full-bridge transformer for 400 W/ 230 V as shown in figure 14</b>			
R21	120 kΩ			IC1	U2008B		
R22	120 kΩ			T1	BC557B		
R23	7.5 kΩ			T2	BC547		
R24	22 kΩ			T3	TE13009		
R25	51 kΩ			T4	TE13009		
R26	20 kΩ			T5	TE13009		
R27	100 kΩ			T6	TE13009		
R28	62 kΩ			D1	BYW55		
R29	220 kΩ			D2	BYW55		
R30	20 kΩ			D3	BYW55		
R31	2.2 kΩ			D4	BYW55		
R32	2.2 kΩ			D5	1N4148		
R33	1.2 kΩ			D6	BZX55C6V8		
R34	100 Ω			D7	BYW55		
R35	100 Ω			D8	1N4148		
C1	22 nF	250 V		D9	1N4148		
C2	220 nF	250 V		D10	1N4148		
C3	100 μF	25 V	El.cap.	D11	BYT52J		
C4	4.7 μF	25 V	El.cap.	D12	BYT52J		
C5	10 nF			D13	1N4148		
C6	100 nF			D14	1N4148		
C7	47 μF	16 V	El.cap.	D15	BYT52J		
C8	100 nF	250 V		D16	BYT52J		
C9	100 nF	250 V		R1	0.68 Ω	0.5 W	
C10	2.2 nF	400 V		R2	K275		Varistor
C11	2.2 nF	400 V		R3	39 kΩ	2 W	
C12	4.7 μF	25 V	El.cap.	R4	680 kΩ		
C13	22 nF	100 V		R5	470 kΩ		Trimmer



R6	1 k $\Omega$		R24	1 $\Omega$		
R7	20 k $\Omega$		R25	100 $\Omega$		
R8	13 k $\Omega$		R26	0.33 $\Omega$		
R9	10 k $\Omega$	Potentiometer	C1	22 nF	250 V	
R10	33 k $\Omega$		C2	220 nF	250 V	
R11	150 $\Omega$		C3	100 $\mu$ F	25 V	El.cap.
R12	56 k $\Omega$		C4	4.7 $\mu$ F	25 V	El.cap.
R13	36 k $\Omega$		C5	10 nF		
R14	1 $\Omega$		C6	100 nF		
R15	100 $\Omega$		C7	47 $\mu$ F	16 V	El.cap.
R16	0.33 $\Omega$		C8	2.2 nF	400 V	
R17	1 $\Omega$		C9	2.2 nF	400 V	
R18	100 $\Omega$		C10	1 $\mu$ F	400 V	
R19	0.33 $\Omega$		L1	0.6 mH		
R20	82 $\Omega$		L2	2 mH		
R21	1 $\Omega$		Tr1	Toroidal core	(10 mm $\varnothing$ )	
R22	100 $\Omega$		Tr2	20 mH	E 42/20 (d = 0 mm)	
R23	0.33 $\Omega$					

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### Layouts

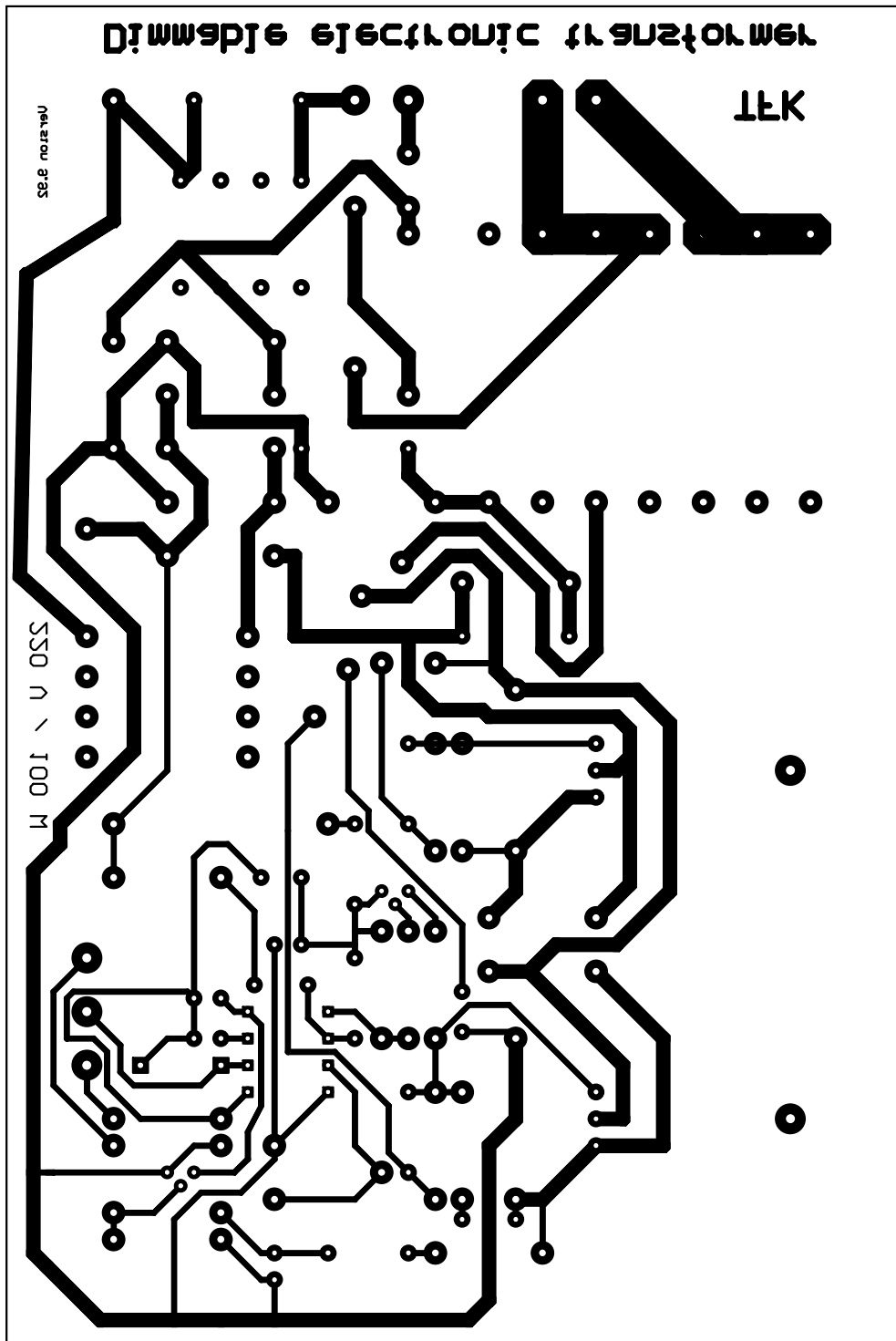


Figure 19. Layout of the voltage controller with U2008B for 100 W/ 230 V (scale 2 : 1)

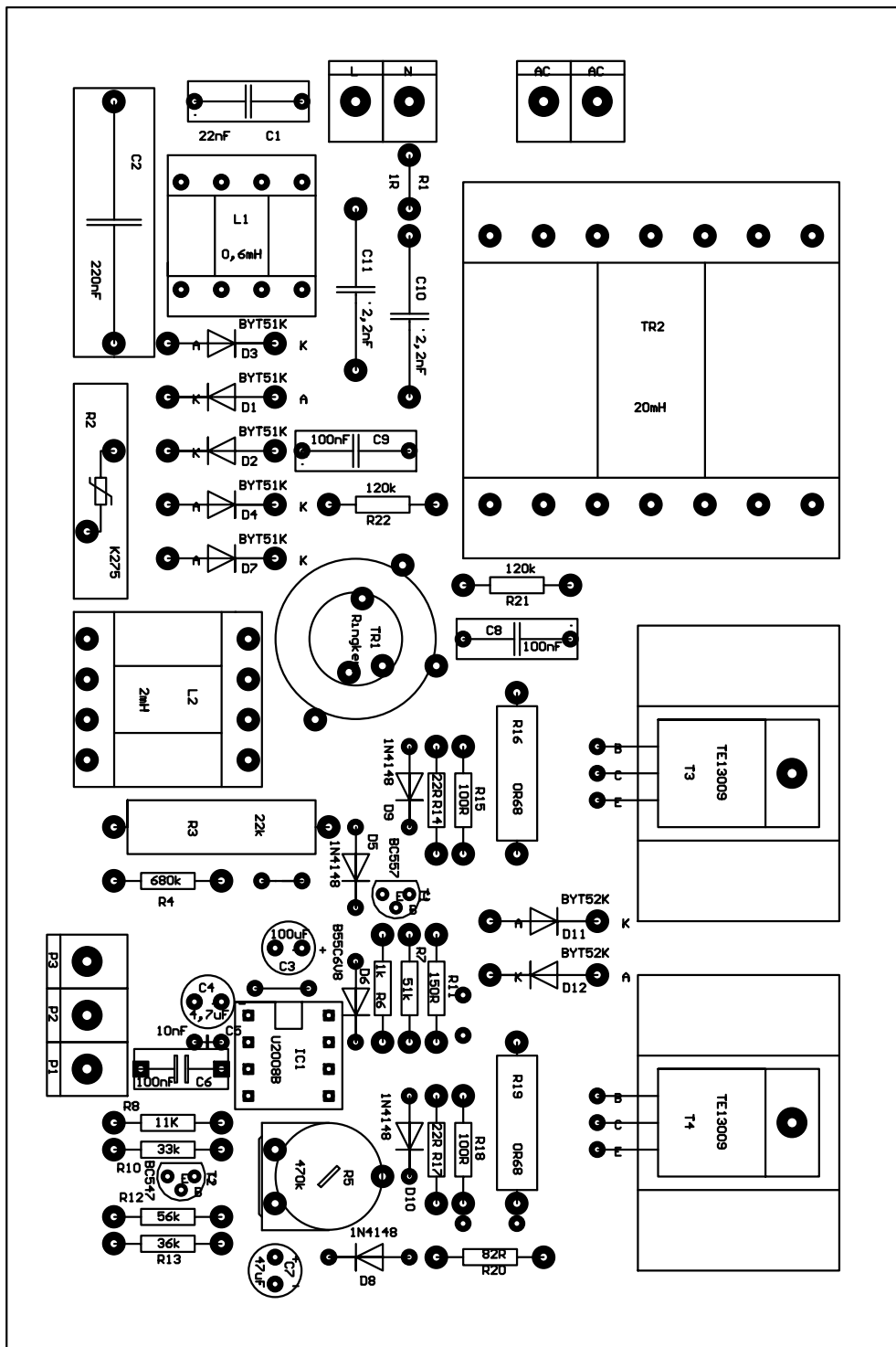


Figure 20. Component layout of the voltage controller with U2008B for 100 W/ 230 V (scale 2 : 1)