



# Phase Switch-off Dimmer DI 300

*This new phase switch-off dimmer allows halogen lamps with step-down electronic transformer, and also normal filament lamps and high-voltage halogen lamps, to be dimmed and switched on or off at the press of a switch.*

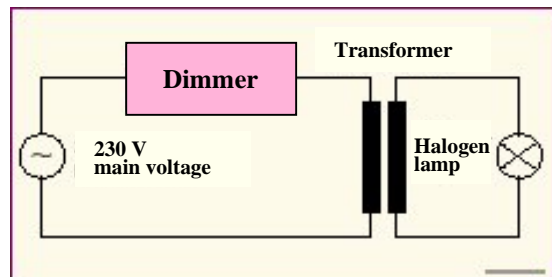
## General

Halogen lamps enjoy great popularity because they combine high light output with low power consumption and compact design, and nowadays are to be found in almost every household.

As power must be supplied at 12V AC, the 230V mains supply must first be stepped down to 12V by means of a suitable intermediate transformer. These step-down transformers may be either conventional, i.e. with a toroidal or iron core, or alternatively, and increasingly often, electronic transformers, characterized particularly

by an electronically regulated output voltage and compact dimensions. Thanks to their low profile, electronic transformers are therefore ideally suited for use, for example, in suspended ceilings in bathrooms and living rooms.

If the brightness of the connected lamps needs to be adjustable, a dimmer is usually inserted in circuit between the 230V mains and the transformer; see Figure 1.



**Fig. 1**  
To control the brightness, a dimmer is inserted in series before the transformer

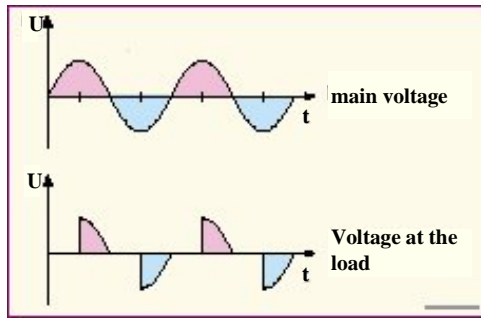


Fig. 2:  
Principle of a  
phase switch-  
on dimmer

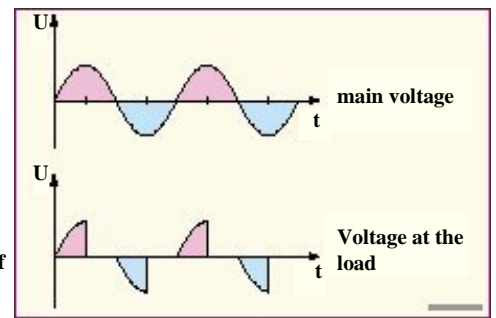


Fig. 4:  
Principle of a  
phase switch-off  
dimmer

However, as described below, conventional and electronic transformers impose different requirements on the series-connected dimmer.

### Phase switch-on dimmers

The principle of phase switch-on is used to control most conventional transformers. With this, the voltage is only applied to the load for a certain interval of time per mains cycle; see Figure 2. The average power output, here 50% of full load, is determined by the length of the time interval. With phase cut-on, the load initially has no power after the mains voltage passes through zero. After an (adjustable) interval of time has elapsed, a triac built into the dimmer is triggered, and this switches on the mains voltage. At the next passage through zero, the hold current for the triac is no longer attained, and the power is switched off. The cycle just described is repeated after each passage through zero. Figure 3 shows the principle of the design of a phase switch-on dimmer.

For the dimmer, conventional transformers represent an inductive load, which produces a phase shift between the voltage and current. Whereas the voltage has already passed through zero, the current has not yet fallen to zero.

Conventional phase switch-on dimmers are not suitable for this type of load, because the triac is not triggered at the “correct point” in the current cycle. Any trigger pulse output by the dimmer before the current has fallen to zero will have no effect. So-called half-wave operation results, which quickly drives the transformer to saturation, and usually results in its failure.

Dimming halogen lamps with conventional transformers thus requires special phase cut-on dimmers, which detect a phase shift either by measuring the current and voltage or by determining the passages through zero, and automatically adjust the timing of the trigger impulse. Examples of dimmers which satisfy these requirements are the halogen lamp primary dimmers described in “ELVjournal” 5/93 or the dimmers in the ELV radio switching system, FS 10.

### Phase switch-off dimmers

For dimming purposes, most electronic transformers require a so-called phase switch-off dimmer. Either the type plate or the instructions for use will then indicate the device is “dimnable” or “dimnable using a phase switch-off dimmer”. Phase switch-off dimmers can also be used with no problems to dim normal filament bulbs and high-voltage halogen lamps.

In contrast to the phase cut-on dimmer, a phase cut-off dimmer switches the mains voltage on immediately at passage through zero, and then off again after an (adjustable) time; see Figure 4. Because a conventional triac cannot be used to switch off the voltage during a half-wave, other alternatives must be explored in order to realize a dimmer of this type. Figure 5 shows the block diagram of the ELV phase cut-off dimmer. The switch used here is a high-voltage MOS-FET. As a MOS-FET is only suitable for switching DC, the mains voltage is first rectified using a bridge rectifier. A control logic unit, in this case a microcontroller, determines the points when the mains voltage passed through zero and switches the MOS-FET on at these points. The mains voltage is thereby applied to the load, here an electronic transformer. After a set interval of time has elapsed, the MOS-FET is switched off, and the load is deenergized. This cycle is repeated after each passage through zero by the mains supply, giving the voltage trace shown in Figure 4 at the load. The switch shown in Figure 5 is used for control purposes, e.g. for switching on and off and for dimming.

### New CoolMOS technology from Siemens

A completely original generation of high-voltage MOS-FETs is used in the new ELV phase cut-off dimmer, i.e. the Siemens “CoolMOS” range. While the familiar MOS structure had reached the limits of its development, and the only way left to reduce the switch-on resistance  $R_{DS(on)}$ , which is the main determinant of the power dissipation, would be to maximize the area of silicon, Siemens’ new “CoolMOS” technology reduces  $R_{DS(on)}$  by a factor of between 5 and 10 for the same chip area. This greatly reduces the power loss in the transistor in its on state. “CoolMOS” technology also sets the standard in terms

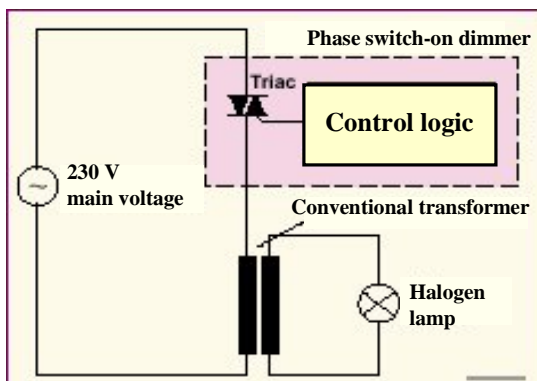
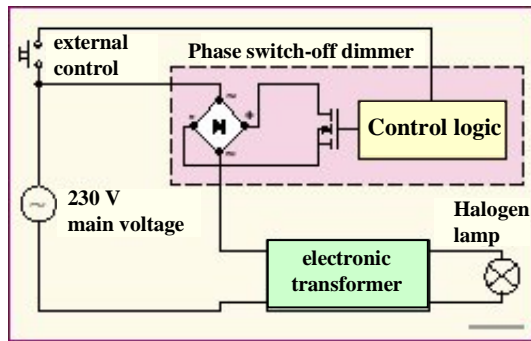


Fig. 3: The operating  
principle of the phase  
switch-on dimmer using  
a triac



**Fig. 5**  
Principle of the phase switch-off dimmer based on MOS-FET

of switching frequency, control power, dynamic losses and size.

This dimmer switch makes use of an SPP 20N60S5 in the TO220 package. Dielectric strength is 600V, the maximum current is 20 A, and its  $R_{DS(on)}$  is a mere 0.19 $\Omega$ . In addition, it has an integral freewheeling diode. Before this, a transistor with comparable data values was only available in the TO 264 or isotope package.

### The ELV phase switch-off dimmer, DI 300

The circuit technology of the DI 300 phase cut-off dimmer is arranged for two-wire operation, so that it can replace a conventional switch or dimmer with no problems. Switching on or off, and dimming, are effected by means of one or more switches in parallel. The ability to connect up several external switches allows the dimmer to be used as a current impulse relay. Thus, a switch can be mounted in different places, allowing the light to be switched on or off and dimmed from these locations.

The dimensions of the circuit board (diameter 55 mm, depth 16.5 mm) were selected to allow it to be installed without difficulty in a normal flush-mounted switch box. It may even be possible to mount it directly behind the switch.

Technical data	
Phase switch-off dimmer	
Mains voltage	230 V 50 Hz
Switched load	25 W to 300 W*
Consumer loads:	electronic halogen lamp transformers, filament bulbs
	high-voltage halogen lamps
Functions:	On, Off, Dim
Control:	one or more switches
Activation times:	50-400 ms: on/off
	>400 ms: dim
Dimensions ( $\varnothing$ xH)	55 x 6.5 mm
* Depends on type of installation -see text	

However, if this method of installation is used, it is essential to ensure adequate insulation and heat dissipation.

Another feature of this dimmer is that, by comparison with conventional phase switch-on dimmers, its operation is almost silent, because the interference suppression coil can be omitted.

The brightness of the connected lamp is set according to the length of time that the switch is kept pressed. A brief press (between 50 and 400 ms) switches the light on or off. If the switch is held down for longer than 400 ms, the brightness of the lamp is adjusted. For example, if the lamp was switched on at full brightness, then after 400 ms the dimmer begins to turn it down. When the minimum brightness is reached, the dimmer reverses to brighten the light, and so on. The direction of change also reverses if the switch is briefly released and then pressed again for longer than 400 ms.

After it has been switched off, the dimmer automatically starts up next time at the level of brightness last used. A special function allows the DI 300 to be switched on at full brightness irrespective of the last brightness level set. To do so, the switch only has to be held down for more than 400 ms when switching on. The dimmer then automatically starts at full brightness.

### Circuit

Figure 6 shows the clear circuitry of the ELV phase cut-off dimmer, which consists of few components. In the switched-off state, the mains voltage is applied to the load at terminal KL1. It is then fed via fuse SI1 to the bridge rectifier comprising diodes D1 to D4. Relative to the rectifier's ground point (anodes D2 and D4), the rectified AC voltage emerges from the cathodes of D1 and D3, and is fed to the high-voltage MOS-FET T1 and

to R9. If the logic described below switches the MOS-FET T1 to conduct, then the rectified mains voltage is short-circuited and the load is energized.

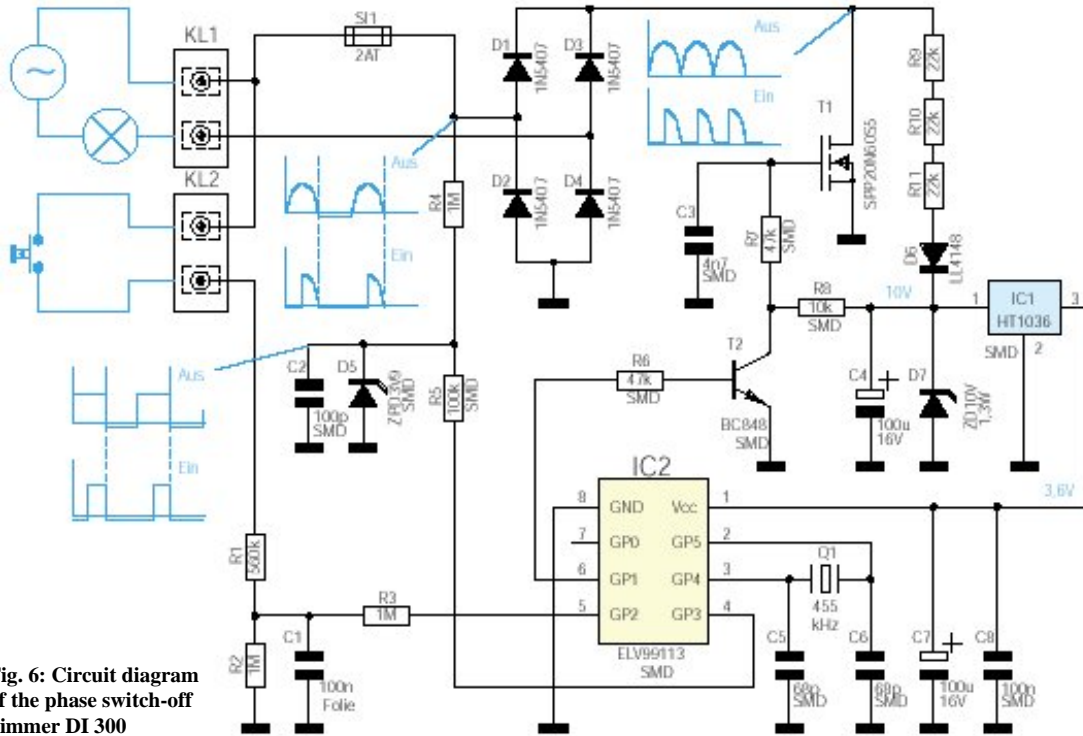
The dimmer itself requires two supply voltages. To trigger the MOS-FET, a 10 V source is required, while to power the processor only 3.6V is required. These two voltages are generated as described below.

The chain of resistors R9, R10 and R11 steps down the rectified mains voltage, Zener diode D7 limits it to a maximum of 10 V. Electrolytic capacitor C4 acts as a filter. D6 prevents the discharge of C4 when the MOS-FET is switched on. Voltage regulator IC1 (HT 1036) provides a voltage stabilized at 3.6 V at its output, pin 3, which supplies processor IC2 at pin 1. C7 and C8 are used here to provide further filtering.

It is particularly important to detect the passage through zero exactly, independent of the phase angle set. For this purpose, the input voltage applied before the bridge rectifier is tapped off via R4, and is limited to 3.9 V by Zener diode D5. As shown on the circuit diagram, the negative edge of the voltage applied to Z-diode D5 is the only one whose timing remains unchanged for different phase angles. This signal is fed to the microcontroller IC2 via resistor R5. It is evident that this negative edge is only available once per cycle of the mains supply, but the MOS-FET needs to be triggered twice per cycle. For this purpose, the microcontroller itself calculates the position of the second passage through zero.

In this application, microcontroller ELV 99113 of type PIC 12C508 is connected to a 455 kHz ceramic oscillator, Q1. This relatively slow operating frequency offers the advantage that the controller only uses 150 $\mu$ A, and the power supply can be implemented in a correspondingly power-saving form.

The MOS-FET is activated from the controller via transistor T2. The 10 V supply is applied to the gate of the MOS-FET via resistors R8 and R7. In order to switch off the MOS-FET, the controller turns T2 on via R6, so that the gate is at ground potential. The RC combination R7, C3, and the gate capacitance of the MOS-FET are such that the switch-off edge is modified, i.e. artificially slowed, so that no further interference suppression measures are necessary to conform to the EMC requirement. The



**Fig. 6: Circuit diagram of the phase switch-off dimmer DI 300**

interference suppression choke for the triac, required with conventional phase cut-on dimmers, is here unnecessary.

To complete the description of the circuit, only a brief explanation of the function of the switch is still required. When pressed, the switch or switches connected to terminal KL2 connect the live phase to resistor R1. The voltage curve corresponds to that at KL1. The applied voltage pulses are integrated in C1 and fed via R3 to the processor. The processor itself clamps the voltage at the port pin GP2 (pin 5) by means of an internal diode. The switching or dimming state is adjusted according to how long the switch is kept pressed.

### Construction

In spite of being fitted with a mixture of SMDs and wired components, the phase switch-off dimmer is quick to construct and involves no difficulties.

**Warning:** Because the device has exposed life-threatening mains voltage points, its construction, testing and installation should be undertaken only by technicians whose training qualifies them for this role. The applicable health and safety at work regulations and VDE provisions must be adhered to.

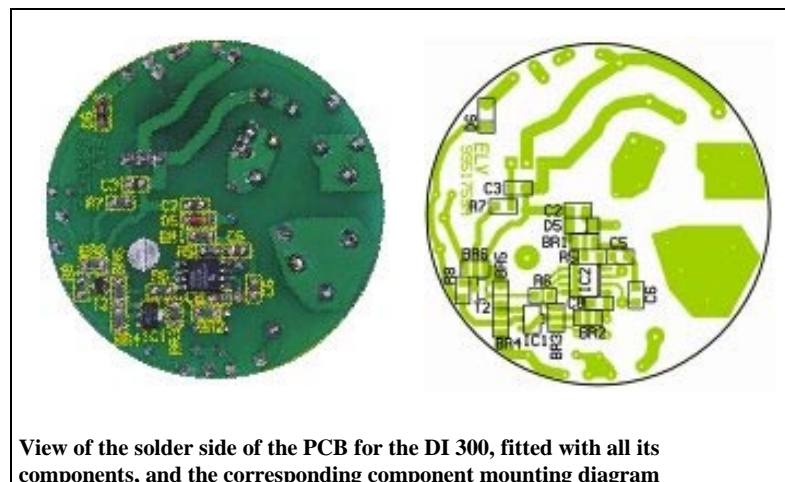
Following this warning, the SMD components are the first to be mounted on the 55 mm diameter one-sided PCB, on the solder side; refer to the component mounting diagram, photo of the PCB and the parts list.

For this purpose, the use of a soldering iron with a pencil-point tip is recommended; please take great care to ensure clean solder-joints.

To mount an SMD component, proceed as follows: The first step is to lightly tin the appropriate pad. Then

position the component using a pair of tweezers, hold it firmly and solder the first side. Before soldering the second side, check for correct positioning.

When mounting the SMD components, the following sequence should be adhered to: resistors and 0Ω bridges, capacitors, transistor, diodes, voltage regulator. When fitting the semiconductors, it is essential to ensure their correct positioning, as also for the subsequent installation of microcontroller IC2; i.e. the markings printed on the PCB



**View of the solder side of the PCB for the DI 300, fitted with all its components, and the corresponding component mounting diagram**

**Parts list:**  
**Phase switch-off dimmer**

**Resistors:**

- 0Ω/SMD.....BR1-BR6
- 10kΩ/SMD.....R8
- 22kΩ.....R9-R11
- 47kΩ/SMD.....R6,R7
- 560kΩ.....R1
- 100kΩ/SMD.....R5
- 1MΩ.....R2-R4

**Capacitors:**

- 68pF/SMD.....C5,C6
- 100pF/SMD.....C2
- 4.7nF/SMD.....C3
- 100nF.....C1
- 100nF/SMD.....C9
- 100µF/16V.....C4,C7

**Semiconductors:**

- HT1036/SMD.....IC1
- ELV99113/SMD.....IC2
- SPP20N60SS.....T1
- BC848.....T2
- 1N5407.....D1-D4
- ZPD3,9V/SMD.....D5
- LL4148.....D6
- ZPD10V/1.3W.....D7

**Miscellaneous:**

- Ceramic oscillator, 455 kHz.Q1
- Mains screw terminals, 2-pin.....KL1,KL2
- Fuses, 2 A, slow-blow.....SI1
- 1 PCB fuse holder (2halves)
- 1 heatsink, SK 13
- 1 pan-head screw, M3 x 8 mm
- 1 nut, M3
- 1 fan-type lock washer, M3

and those on the component must agree.

When the SMD components have all been mounted, the next step is to populate the component side with the



The fully assembled PCB for the DI 300, viewed from the component side, and the corresponding component mounting diagram

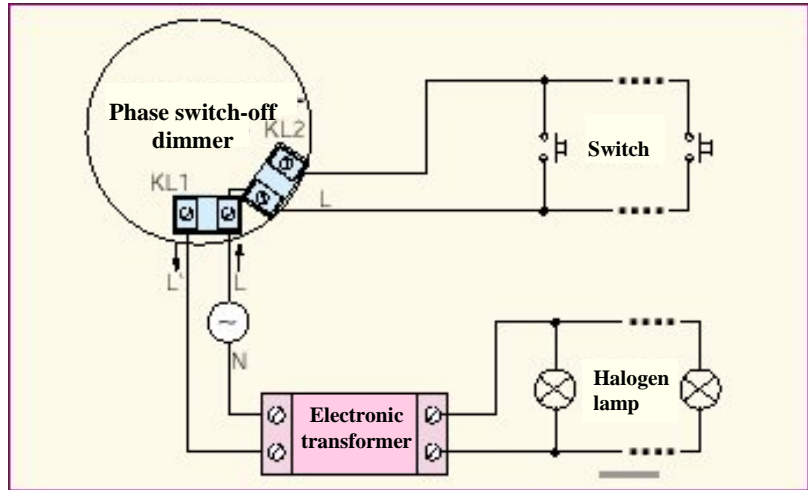


Fig. 7: Installation of the DI 300 dimmer

resistors and capacitors, the ceramic resonator, the fuse-holder halves and the Z-diode. As will be seen from the component photo, diodes D1 to D4 should be mounted upright. When mounting the screw terminal strips, care must be taken that they lie flat on the PCB, and the openings are toward the outside.

After the connecting pins on the MOS-FET have been bent backward through 90° at a distance of 3 mm from the package, it can then be mounted. Push the M3x8mm pan-head screw through the appropriate hole in the PCB from its underside. On the component side, the heatsink and the MOS-FET are then put over the screw. These are followed by the fan-type lock washer and the M3 nut. After the screw has been done up tight, the transistor can be soldered.

Insertion of the fuse into its holder completes the assembly work; check that the components are inserted correctly. Remove any unwanted solder bridges which are present.

**Installation**

Figure 7 shows how the dimmer is connected up. Terminal KL1 is used to loop the dimmer into the power supply circuit for the lamp. The incoming live phase L is connected to the right-hand terminal connector, while the load should be connected to the left-hand terminal connector "L". The neutral conductor N is not required on the dimmer itself, because of its two-wire operation.

One or more switches can be connected to KL2. As shown in Figure 6, the L phase is connected internally in the dimmer from KL1 through to KL2. If a switch is pressed, the L phase is switched through to the control input. Switching the phase line has the advantage that only one control line is required, provided that the phase is also available at the point where the switch is installed. The only important point is that it must be the same (!) phase, and that the switch is approved for such 230 V applications.

The dimensions of the dimmer were selected so that the circuit board (diameter 55 mm, depth 16.5 mm) can be installed without difficulty in a normal recessed switch box.

It is even possible in some cases to mount the board directly behind the switch; however, if this is done, great care must be taken to ensure appropriate insulation and adequate heat dissipation. Depending on the installation location, the power handling capacity of 300 W may be significantly reduced

An alternative would be to mount the dimmer in a suitable housing, wherever required, for example in a suspended ceiling directly upstream from the transformer. Adequate insulation and heat dissipation facilities are again important.