Application Note DK9222-0310-0010

Bus Terminals

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Universal dimmer
Low-voltage halogen dimmer
Ethernet dimmer
Leading edge phase control
Trailing edge phase control
Short-circuit-proof
Network-capable
KL2751
KL2761

Basic principles of the dimmer function and network capability

This application example describes the basic principles of the dimming of light, the important aspects concerning the individual types of dimmer (leading edge phase control, trailing edge phase control, universal) and the advantages of the use of a network-capable universal dimmer.

Basic principles

In order to dim the intesity of a light bulb, the flow of current is reduced, which corresponds to a regulation of the brightness. Three principles can be employed for this: voltage divider, leading edge phase control and trailing edge phase control. The voltage divider is not used because of its energetic inefficiency: the voltage for the light generation is divided by an adjustable pre-resistor; the proportion of the unused power to generate light is dissipated by the resistor and converted into heat energy. Phase control dimmers work considerably more efficiently, since in this case the current is switched on and off by means of electronic circuits. The light bulb is switched at a frequency that is not discernable to the eye. Since the flow of current is interrupted during the dead time, the power dissipation is considerably reduced in comparison with the voltage divider. The ratio of the switch-on time to the switch-off time determines in both principles the flow of current or the quantity of emitted light. The basis of both principles is the sine wave of the mains voltage. At a frequency of 50 Hz the voltage changes its polarity 100 times per second; it therefore also reaches the zero crossing point, at which there is freedom from both current and voltage for a brief moment, 100 times per second.

Dimmer types

Electronic phase control dimmers control the effect produced by the light source by only letting the current flow over a certain section of the alternating voltage half-waves. In the case of 230 V general-purpose lamps ('incandescent lamps'), the operating

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mode of the dimmer is unimportant because of the purely ohmic load. For all illuminants that are connected via electronic ballasts (EBs), such as low-voltage halogen spots, the construction of the transformer is decisive for the applied control principle. It should also be noted that mixed loads are not controlled: an ohmic load cannot be controlled together with an inductive load in a the same circuit, even if the dimmer is suitable for both load types. The dimmer type and the type of the connectable loads are identifiable by pictograms.

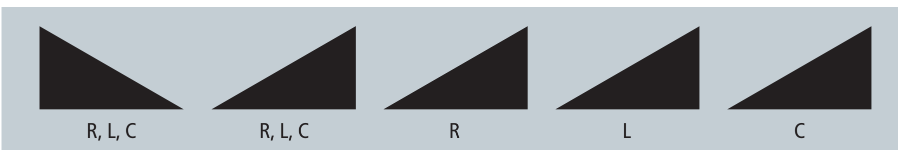

Fig. 1 Meaning of the pictograms: R = ohmic, L = inductive, C = capacitive, descending triangle = leading edge phase control, ascending triangle = trailing edge phase control

Inductive loads – leading edge phase control

Low-voltage halogen lamps with conventional, inductive (= wire-wound) transformers are controlled by thyristor dimmers based on leading edge phase control. In the leading edge phase control technique, the switch-on point of the switch is changed in relation to the mains voltage half-wave. The thyristor thereby becomes conductive at a controllable point within the voltage half-waves; the flow of current is automatically interrupted at the next zero crossing of the sine half-wave. This ensures that no inductive voltage peak occurs when switching off.

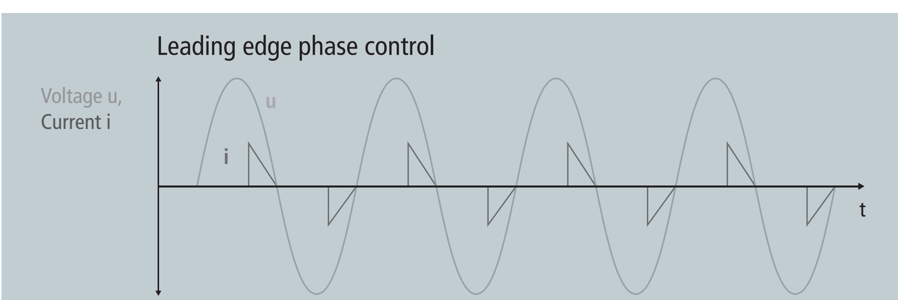

Fig. 2 Change of switch-on point with leading edge phase control

Capacitive and ohmic loads – trailing edge phase control

Trailing edge phase control is used with electronic low-voltage transformers. In the trailing edge phase control technique, the switch-off point of the switch is changed in relation to the mains voltage half-wave. The current begins to flow exactly at the zero crossing of the voltage wave; the transistor dimmer terminates the flow of current at a controllable point within the half-wave. Advantages of this circuit: the flow of current can be interrupted at any time; very accurate control is possible and the flow of current is also interrupted immediately in the case of an overload or a short-circuit. The generation of current peaks on input capacitors of the EBs is avoided, since the flat rise of the sine wave is used in order to charge the capacitor. The voltage

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required for the load is approached 'softly'; this accurate regulation protects the load. Trailing edge phase control dimmers are provided with a current limiter function, which reduces the output voltage in the case of overload. Furthermore, trailing edge phase control generates very little electromagnetic interference. Unfortunately, the types of switches used are very sensitive and are destroyed even by brief overloading. As prevention therefore, complex protective circuits are integrated. 230 V general-purpose lamps (ohmic loads) and lamps with EBs (capacitive loads) can be used as loads.

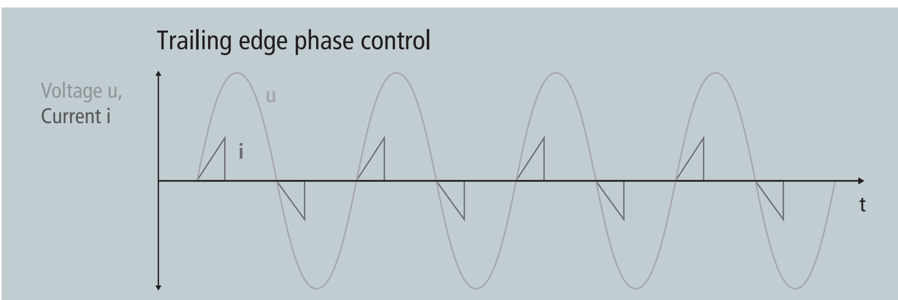

Fig. 3 Change of switch-off point with trailing edge phase control

Universal dimmer

Trailing edge phase control cannot be used with capacitive loads, because a sudden increase in voltage would cause an extremely high current flow. On the other hand, trailing edge phase control is not suitable for inductive loads, because a voltage peak would occur when switching off the current. If a wire-wound transformer is operated in error with a trailing edge phase control dimmer, then damage to the power transistor and the protective components of the dimmer is to be expected due to the resulting inductive voltage peaks. Additionally, damage to the cable insulation and the transformer windings can occur. If using wire-wound transformers, it is particularly important to ensure a high degree of stability and symmetry in the leading edge phase control dimmer, in order to prevent the development of direct current components in the primary winding of the transformers with risks of overheating and cable breakage. In order to avoid this selection problem, universal dimmers have been developed in which both control principles are implemented. They are particularly advantageous and uncomplicated to handle, because they automatically recognise the type of load when switching on the connected mains supply and therefore use the appropriate control principle. However, the electrical behaviour of the connected load must also be uniform in this case. A further advantage of universal dimmers is that a change of the lighting elements (i.e. a change of the type of load) does not entail changing the dimmer, because it is suitable for every load (inductive, ohmic and capacitive).

Practical problem: uniform brightness regulation

In practice, the operator expects that a quarter of a turn of the rotary switch of the dimmer will also lead to a change in the brightness by a quarter. In case of conventional phase controls without integrated characteristic, however, the expected effect does not occur, since only the switch-on/off point is controlled and not the power. Since the brightness corresponds to the power, a change of the switching point by 5 % does not result in an actual change in the brightness of 5 %. Depending upon the type of control and the point of the output values within the sine half-wave, the actual control effect will be considerably stronger or weaker.

The visible light corresponds to the power P supplied to the lamp, which, in the case of AC voltage,of the product of the time-dependent variables î and û. Due to the multiplication of the two variables, the power is also positive in the negative half-wave. The momentary values î and û have a different value depending on the point in the mains wave, thus their product, the power P, is also different at different points in the mains wave. Without an integrated characteristic the step width on the time axis is constant. The power within the constant step width is not constant, since the amount of space below the sine wave changes per step. The constant step width is particularly disadvantageous when regulating around the peak of the sine wave: A step width reduction at 50 % by ±10 percentage points corresponds to a brightness adjustment of considerably more than 20 %. Therefore, the operator is inevitably compelled to adjust more precisely in order to achieve a linear change of brightness. In practice, it is therefore difficult to achieve adjustment with high repeatability. If controlled illumination of the room is desired, one is compelled by means of commissioning to trace a linearisation characteristic and subsequently to enter it in the controller by hand accordingly.

Network-capable dimmers with linearised characteristic

The KL2751 and KL2761 Bus Terminals are universal dimmers with linearised characteristic for the uniform brightness regulation of lighting elements. Capacitive, inductive and ohmic loads can be connected to the single-channel universal dimmer terminals. Since the terminals are capable of both types of phase control, they can also be used as power switches for the control of AC loads, depending on the power requirement of the connected load (KL2751: 300 VA, KL2761: 600 VA). Furthermore, the terminals can be integrated in any control environment via Bus Couplers and are thus among the few currently available network-capable universal dimmers that are not based on the DMX protocol standard normally used for professional lighting (as of 09/2009).

The terminals offer many advantages to the user and are particularly uncomplicated to handle. As is typical of universal dimmers, there is no need to exchange the dimmer if the type of load has changed (R, L, C). The terminal recognises the connected load automatically after switching on the mains supply (not after switching on the consumer!) and applies the appropriate control principle. Furthermore, the terminal is short-circuit-proof: Without the employment of a short-circuit-proof dimmer, the fuse must also be exchanged as a rule when exchanging the lamp, since the fuse is also damaged by the short-circuit when the filament burns out. The short-circuit resistance of the KL2751/61 prevents damage to the fuse, so that no maintenance work is necessary inside the control cabinet when exchanging the lamp. The terminal is particularly discrete in the control cabinet because, with a width of only 12 mm, it takes up the space of two conventional rail mounted terminals, like almost all Bus Terminals from Beckhoff Automation GmbH. It is thus four times smaller than a conventional universal dimmer for DIN rail mounting. The dimming behaviour of the KL2751/61 is considerably more consistent than that of the conventional universal dimmer due to the internal linearisation. As opposed to a constant step width, a brightness-dependent step width is

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selected in the KL2751/61, so that the power increase per step remains constant. A change of the process data by, for example, 27 % also produces a change of brightness of 27 %, independent of the output value.

– 1-channel universal dimmer terminal, 230 V AC, 300 VA (W) **www.beckhoff.com/KL2751**
– 1-channel universal dimmer terminal, 230 V AC, 600 VA (W) **www.beckhoff.com/KL2761**
– The modular automation components for building automation **www.beckhoff.com/building**