14.2 SEMIKRON Pulse Transformers

Code Designation System

SK PT 27 a 10

- SEMIKRON component — SK
- Pulse transformer — PT
- Case size — 27
- Radio of windings — a
  - a, i 1:1
  - b, k 1:1:1
  - c 2:1
  - d 3:1
  - e 3:1:1
  - f 4:1
  - g 2:1:1
  - h 1:1:1:1
- Type number (approximate ∫ vdt value [µVs]/100) — 10

1. Introduction

SEMIKRON impulse transformers are intended to be used with the whole family of SEMIKRON thyristors and also with non-SEMIKRON products.

In many electronic power applications pulse transformers are generally used for firing thyristors and triacs, and for the control of power transistors and darlingtons. In most cases, the controlling pulse comes from a trigger circuit at low voltage level (10 to 30 V), whilst the transformer secondary winding normally is connected to higher voltages (220 to 600 Vrms).

The galvanic isolation through the pulse transformer improves the system and protects the controlling circuit against spikes and transients from the power circuit.

The use of SEMIKRON pulse transformers offers the following advantages:

1. High isolation between the control circuit and the power side (2.5 - 4.0 kVrms).
2. Low coupling capacity, achieved thanks a special winding technique, avoids transient effects from the power line to the control circuit.
3. High value of pulse amplitude and duration, due to special magnetic materials with high magnetic permeability, and also low values of magnetising current.
4. Well coupled magnetic coils assure low stray inductance levels and low rise times (high di/dt values).
5. Very compact sizes and very low core losses due to special magnetic material (Ferrite able to work up to 150 kHz).

According to the application the specified technical data may differ from case to case, as follows:

- output voltage with no load	5 - 15 V
- trigger current	100 mA - 1 A
- rise time	0,5 - 5 µs
- pulse width	10 µs - 1 ms
- operation frequency	5 - 10 kHz

The simplified model of a pulse transformer and its parameters is shown below:

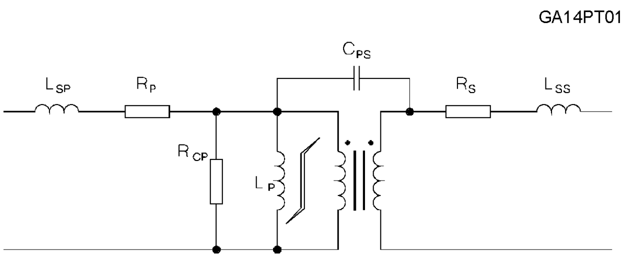

Fig. 1 Model of an impulse transformer

L_{sp} = primary stray inductance
C_{ps} = coupling capacity between primary and secondary
R_s = secondary wiring resistance
L_{ss} = secondary stray inductance
R_p = primary wiring resistance
L_p = magnetising inductance
R_{cp} = core power losses

2. Explanations of Technical data

- **Transformation ratio**: shows the number of coils and their relation, e.g. 3:1:1.
- Voltage-time integral ∫ vdt, pulse width t_p

The voltage which is induced in the secondary winding of a transformer is given by the product of the inductance L_p and the rate of change of current in the primary winding. A constant current flowing in the primary will produce no secondary voltage. When a rectangular shaped current pulse is applied to the primary winding a voltage is induced in the secondary during the rise time of the pulse. This voltage does not immediately decay when the primary current reaches its constant value but remains for a time

t_p which is inversely proportional to the voltage V. More exactly expressed: the voltage-time integral for a given transformer is a constant K:

$\int$ vdt = K

The area under the curve which plots the waveform of voltage against time gives the value of the above integral. With a rectangular pulse this integral is given simply by the product V · t_p where V is the amplitude of the pulse and t_p is its width.

Since with thyristor firing circuits the amplitude of the pulse is determined by the gate characteristic and by the series resistances in the circuit, then for a given transformer, the above voltage-time integral effectively defines the resulting pulse width.

- **Transfer area:** or voltage-time integral is the minimum value for the voltage-time area measured on a secondary winding in a no-load condition for an unipolar pulse until it reaches the saturation.

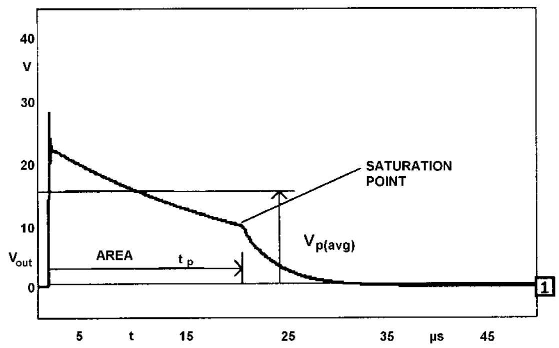

Fig. 2 $\int$ v.dt = V_{out} · t_d = 331 µVs (the whole area under the curve)

- The example shows a **SKPT 25a3** transferring a pulse of 24 V amplitude from a pulse generator with R_g = 50 Ω and the point where it starts to go into saturation; the value of the integral represents the maximum pulse width t_p and the average pulse amplitude that can be transferred before reaching saturation. In the example, t_p = 20,7 µs and V_p = 16 V ($V_p \cdot t_p$ = 331 µs) can be used, without going into saturation.
- **di/dt, rise time t_r and peak current I_M:** For the reliable firing of a thyristor the firing pulse, as well as having an adequate amplitude, must also possess a sharp leading edge. To achieve this, pulse transformers require low stray inductance (will be explained later) and tight coupling between primary and the secondary winding.
The rise time t_r is proportional to the time constant formed by the stray inductance L_s and the load resistance R_L.

$$t_r = \frac{L_S}{R_L} \qquad (1)$$

The load resistance is the sum of all d.c. resistances in the gate circuit. To find the rise time and di/dt a conventional circuit incorporating a speed-up RC network, which produces a peak I_M at the start of the pulse is used as shown:

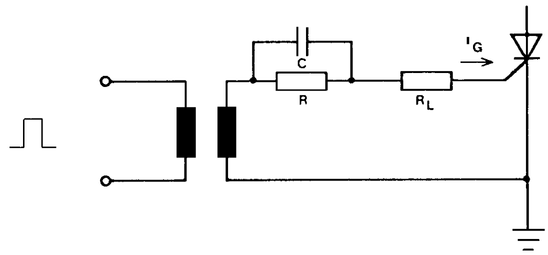

Fig. 3 Circuit for determining t_r and I_M

The rise time of the current is given by

$$\frac{dIG}{dt} = \frac{I_2 - I_1}{t_r} \qquad (2)$$

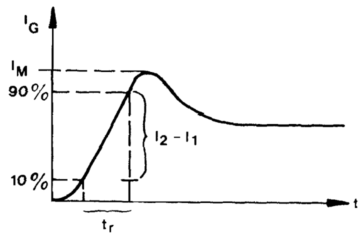

Fig. 4 Current waveform

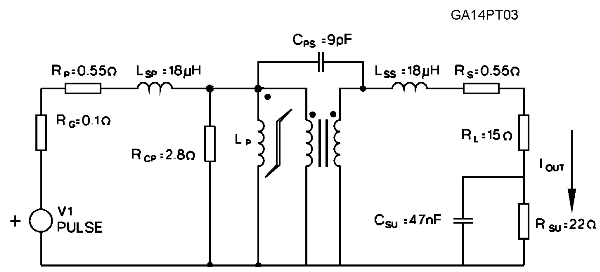

Fig. 5 model of a SKPT 25a3

The same circuit is used to determine the highest obtainable peak current I_M at the load (gate circuit) resitance R_L.

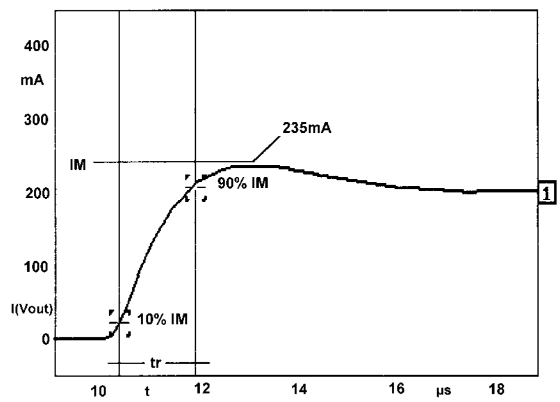

Fig. 6 SKPT 25a3 measurement of rise time

The diagram Fig.6 shows the **SKPT 25a3** and the corresponding rise time. The di/dt may be evaluated from (2):

$$\frac{\Delta I}{t_r} \text{ e.g. } \frac{188\,\text{mA}}{1,56\,\mu\text{s}} = 120 \cdot \frac{\text{mA}}{\mu\text{s}}$$

- **Stray inductance L_S:** The value of this parameter depends mainly on the mechanical layout of the transformer and shows the coupling between core and/ or coils. Good coupling means low stray inductance. Therefore, coils with a high number of turns tend to have higher values of L_s. It can easily be measured by putting the secondary side in short-circuit and connecting an LC-meter at the primary side. If L_s has a high value, di/ dt will be limited and then tr becomes bigger.
  The following formula gives the relation between their two parameters

$$L_S = L_{Stotal} = L_{sp} + L_{ss} \quad (3)$$

then

$$t_r = \frac{L_{Stotal}}{0,83 \cdot (R_L + R_S + \{N_s/N_p\}^2 \cdot R_p)} \quad (4)$$

$$\frac{di}{dt} = \frac{V_{in}}{L_{Stotal}} \quad (5)$$

- **Coupling capacitance C_{ps}**: the coupling capacitance between primary and secondary does not have an influence on the electrical results of the transformer, but in circuits in which sudden high jumps in potential occur, such as in four quadrant converters or in many self-commutated circuits, this value must be minimised. Otherwise the charging current of this capacitance may cause undesired firing of the thyristor. For this reason, transformers with high numbers of turns, have a screen inserted between the primary and the secondary windings.
- **Magnetising inductance or primary inductance (L_p)**: this parameter depends on the maximum permeability of the core material. The final value must be found with a tolerance - 30 % + 50 % and depends directly on the core temperature. With high permeability materials, we need less turns to achieve the desired L_p; low values of L_p make the transformer more suitable to saturation.
- **Nominal voltage (V_{rms}):** this is the voltage in the secondary circuit of the transformer. Creepage distances, isolation tests and isolation distances will be found with this value, and it determines the maximum working voltage between two single windings.
- **Corona voltage (V_k):** this voltage is the maximum working voltage before "Corona effect" starts. For all SEMIKRON types, this value is 1,5 ... 1,75 x U_{rms}.
- **Isolation test voltage (V_{isol}):** test voltage winding to winding. The high voltage test checks the galvanic separation of the transformer windings, in particular the dielectric strength and freedom from partial discharge.
  The test is acc. to VDE 0550, part 1.
  The specifications on isolation voltage for equipment are included in IEC Publication IEC 146-1-1: 1991, respectively with EN 60146-1-1: 1993 clause 4.2.1.
  (= VDE 0558 T1-1: 1993-04) or EN 50 178: 11.1997 = DIN EN 50 178 (VDE 0160) 4.1998
- **Low losses:** thyristors firing transformers operate with pulse currents and high voltage. In windings losses can be reduced by achieving low ohmic values; in cores, losses are smaller by choosing suitable materials for high frequency operations.

3. Ratings, Characteristics and mechanical outline see pages B 14 – 103 etc, "L_{ss}" = "L_s"

4. Application examples

The link between the control and the thyristors is the trigger unit. Its function is to produce the required gate trigger current pulses whose frequency, phase, sequence, etc., are determined by signals supplied through the control or regulation electronics.

- **Shape of the trigger pulses:** under critical rate of rise of on-state current, with a steeply increasing main current it is necessary to supply a trigger pulse of high amplitude ($\cong 5 \cdot I_{GT}$) with a steep leading edge (≥ 1 A/µs). However, even when the current in the commutation circuit only increases relatively slowly, with a parallel connected transient voltage suppression RC snubber network, the steeply increasing discharge current of the capacitor flows through the thyristor when it fires. It is therefore recommended to use high amplitude, steep trigger pulses in all circumstances.
  This is particularly important with parallel or series connected thyristors since high amplitude, steeply increasing trigger pulses will ensure sirnultaneous firing.
  In order to determine whether a trigger unit with known values of short circuit current I_K and open circuit voltage V_o is adequate, its output characteristic as defined by these values is plotted on a diagram showing also the gate characteristic of the thyristor in question. For this purpose the gate trigger curve, which has normally a logarithmic scale, is re-drawn in a linear scale in Fig.7 such that the output characteristic of the trigger unit is more easily displayed as a straight line connecting I_K and V_o, see Fig. 7 next page.
  The actual gate characteristic of one particular thyristor of the type in question will lie somewhere between the limiting curves on the diagram. Hence, the possible crossing points of the gate characteristic with the trigger unit output characteristic will lie between the points A and B on the load line.

The width of the trigger pulse should not be less than 10 µs. The value of latching current as specified in SEMIKRON data sheets is valid for trigger pulses of this duration. The thyristor needs about 100 µs to be fully switched-on. See page A - 39: di/dt and A - 40: I_L. As the gate pulse width increases, the minimum gate trigger current and the latching current are reduced.

When a rectifier has a load with back e.m.f., then the thyristors can only trigger when the instantaneous value of the alternating input voltage is higher than the back e.m.f. In order to be sure that the commutation will be achieved, it is necessary in this case to use comparatively wide trigger pulses. The extreme case is the a.c. controller with an inductive load. As a result of the phase shift between current and voltage here it is necessary to have a pulse duration of (180-α)°el., i.e., at 50 Hz up to 10 ms.

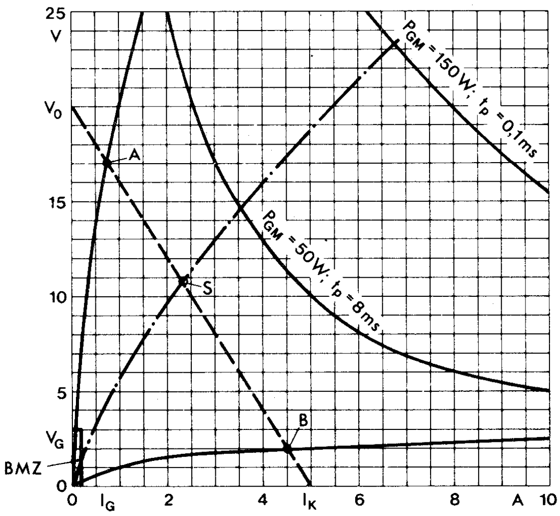

Fig. 7 Gate trigger characteristics (see also B 3 – 16, Fig. 9)

The width of the trigger pulses should not be made unnecessarily long, since long pulses result in a significant gate power dissipation, account of which must be taken when calculating the overall power loss of the thyristor. Necessarily, the limiting power values P_{GM} as shown in Fig.7 should in no circumstances be exceeded, otherwise the thyristor could be destroyed. Even when the power loss is well below these maximum values, however, account must be taken of it when the rating of the thyristor is calculated.

In addition to the above, the trigger unit also becomes more expensive with increased output power. Wide pulses mean for the pulse transformer a large voltage-time integral, and that means a larger transformer. For this reason, instead of a single long pulse, a series of short pulses (with a frequency from 5 ... 10 kHz) are often used, **the pulse train solution**. If the gaps between the pulses cause problems, then a second chain of pulses can be superimposed such that a continuous long pulse is still achieved. In this case the pulse transformer needs only be dimensioned for the short duration pulses (e.g. with 7 kHz, t_p = 70 µs).

- **Circuits examples**: we are showing in the following examples two typical applications for impulse transformers.

1. **The first example**: simple trigger circuit with current limiting resistor in the primary side is shown in Fig. 8

Low L_p → fast decreasing of I_g

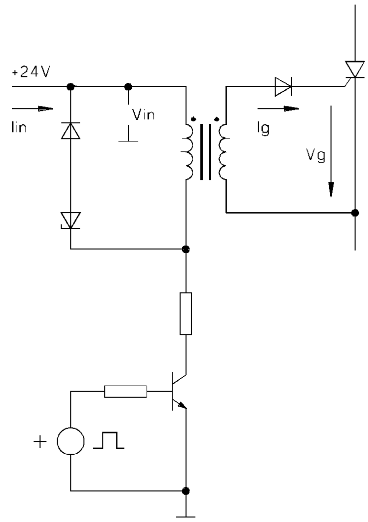

Fig. 8 Trigger circuit with SKPT25a3

$$V_g = V_{in} \cdot \left\{\frac{N_s}{N_p}\right\}^2 - V_d \qquad (7)$$

$$I_g = \frac{I_{in} - I_{mag}}{\frac{N_s}{N_p}} \qquad (8)$$

The voltage-time area is found in Fig. 9 during the time t_p (e.g. ≅ 56 ms) and must be smaller than the maximum value ∫ U.dt given in the data sheet (e.g. 350 µVs for SKPT 25a3).

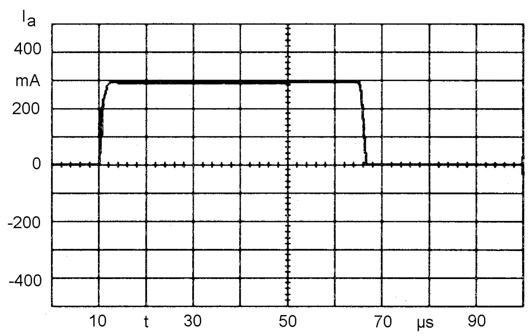

Fig. 9a Input current I_{in}

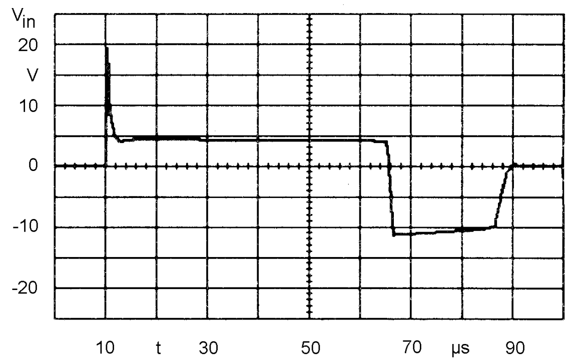

Fig. 9b Input voltage V_{in}

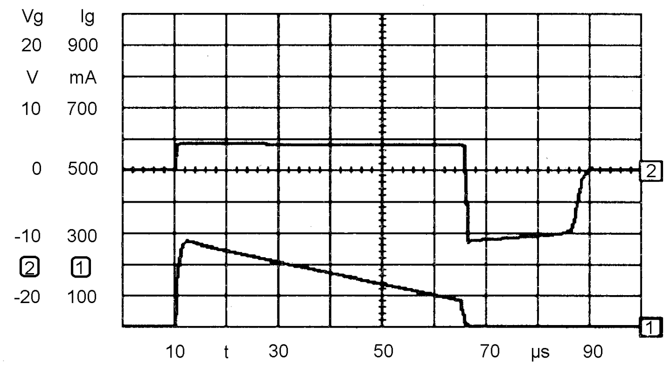

Fig. 9c Output voltage v_g (curve 2) and output current i_g (curve1) of SKPT 25a3 (see Fig. 8)

2. **The second example:** The pulse transformer is intended to deliver long pulses without using big pulse transformers ($t_p \geq 1$ ms) as needed for inductive loads up to $t_p = 180° - \alpha$). The solution is as follows

Superposition of two pulse trains 1 and 2 of 5 to 7 kHz using 2 SKPT 25a3.

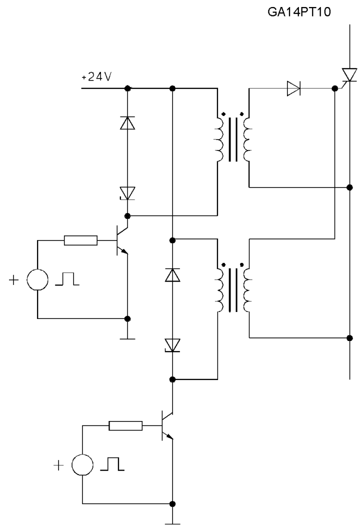

Fig. 10 Circuit of the superposition of two pulse trains of short pulses of two SKPT 25a3

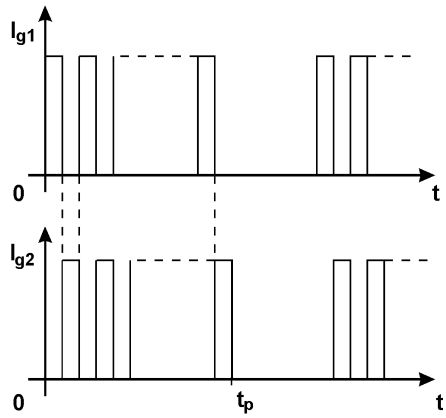

Fig. 11 The two pulse trains of gate current overlapping over $t_p = 180° - \alpha$ for inductive loads

14.3 Fans

Type Designation System

SK F 16 B -230

SEMIKRON Component — SK
Fan — F
Suitable heatsink type (P16) — 16
Version: B — B
Input voltage (230 V AC) — -230

Captions of the Figures

