

TRANSISTOR PROTECTION BY TRANSIL™

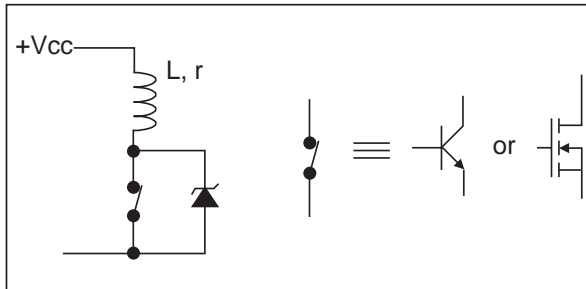
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INTRODUCTION

In a large number of applications, we find the circuit in Fig. 1 where a TRANSIL™ is used to protect a switch that controls an inductive load. The switch can be a bipolar or a MOS transistor.

The purpose of this paper is to calculate the dissipated power in the TRANSIL™ and the pulse current duration.

Fig. 1: Basic diagram

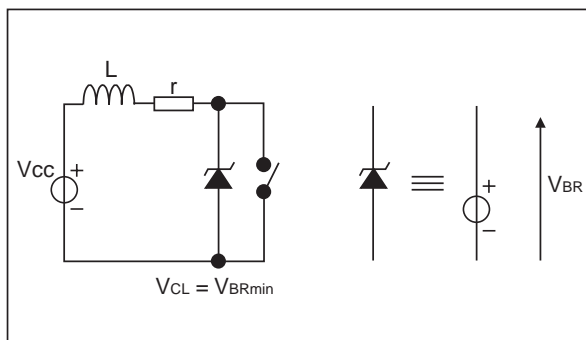


1. CIRCUIT MODELLING

When the switch turns off we use the equivalent circuit represented in Fig. 2.

The worst case is to consider $V_{CL} = V_{BR \min}$. This hypothesis will be used in all formulae.

Fig. 2: Equivalent Circuit



V_{CL}	Clamping voltage
V_{BR}	Breakdown voltage

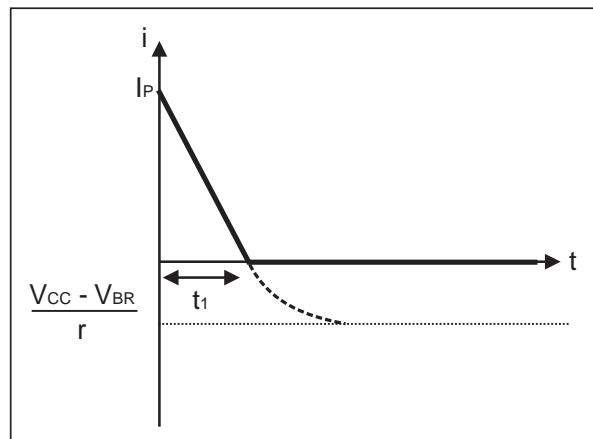
2. CURRENT IN THE TRANSIL

We can express the current i through the TRANSIL by the following formula:

$$i = \left(I_p + \frac{V_{BR \min} - V_{cc}}{r} \right) \exp(-r \times t/L) + \left(\frac{V_{cc} - V_{BR \min}}{r} \right)$$

I_p is the current through the coil when the transistor switches off. Fig. 3 shows the current variation versus time.

Fig. 3: Current Waveform



t_1 can be calculated by:

$$t_1 = -\frac{L}{r} \times \ln \left(\frac{V_{BR \min} - V_{cc}}{V_{BR \min} - V_{cc} + r I_p} \right)$$

APPLICATION NOTE

3. TRANSIL POWER DISSIPATION

We can consider two cases, single pulse operation and repetitive pulse operation.

3.1. Single pulse operation

In this case, in order to define a TRANSIL we need the peak power P_P and the pulse current standard duration t_P .

P_P is given by: $P_P = V_{BR\ min} \times I_P$

If we approximate the pulse current with a triangle, the standard exponential equivalent pulse duration t_P is calculated by the formula:

$$t_P = -\left(14 \frac{L}{2r}\right) \times \ln\left(\frac{V_{BR\ min} - V_{cc}}{V_{BR\ min} - V_{cc} + rI_P}\right)$$

The energy in the TRANSIL can be expressed by:

$$W = \left(\frac{V_{BR\ min} \times L}{r}\right) \times \left[I_P + \left(\frac{V_{BR\ min} - V_{cc}}{r}\right) \ln\left(\frac{V_{BR\ min} - V_{cc}}{V_{BR\ min} - V_{cc} + rI_P}\right) \right]$$

When r tends to zero we find:

$$W = \frac{1}{2} L I_P^2 \left(\frac{V_{BR\ min}}{V_{BR\ min} - V_{cc}}\right)$$

3.2. Repetitive pulse operation

In repetitive pulse operation the power dissipation can be calculated by the following formula:

$$P = F \times \left(\frac{V_{BR\ min} \times L}{r}\right) \times \left[I_P + \left(\frac{V_{BR\ min} - V_{cc}}{r}\right) \ln\left(\frac{V_{BR\ min} - V_{cc}}{V_{BR\ min} - V_{cc} + rI_P}\right) \right]$$

When r tends to zero we find:

$$P = \frac{1}{2} F L I_P^2 \left(\frac{V_{BR\ min}}{V_{BR\ min} - V_{cc}}\right)$$

Where F is the switching frequency.

4. EXAMPLE OF APPLICATION

A typical application would be a switched coil supplied by a battery. The different parameters of the application are:

$V_{CC} = 14V$, $L = 10mH$, $r = 3$, $I_P = 4A$

TRANSIL: SM6HT36A, $V_{BR\ min} = 34.2V$

4.1. Single pulse

We find

$$P_P = 32.4 \times 4 = 136.8W$$
$$t_P = \frac{-14 \times 10 \times 10^{-3}}{2 \times 3} \ln\left(\frac{34.2 - 14}{34.2 - 14 + 3 \times 4}\right)$$
$$t_P = 1.08ms$$

The datasheet gives $P_P \approx 450W$ for $t_P = 2ms$, so the SM6HT36A can be used in this application.

4.2. Repetitive pulse operation

The switching frequency is equal to 10Hz so

$$P = 10 \times \frac{34.2 \times 10 \times 10^{-3}}{3} \times \left[4 + \left(\frac{34.2 - 14}{3}\right) \ln\left(\frac{34.2 - 14}{34.2 - 14 + 3 \times 4}\right) \right]$$
$$P = 980mW$$

We have:

$$T_j = P \cdot R_{th(j-a)} + T_{amb\ max}$$

With $T_{amb\ max} = 50^\circ C$, $R_{th(j-a)} = 75^\circ C/W$ (with copper surface under each lead equal to $2.5cm^2$) we find:

$$T_j = 0.98 \times 75 + 50 = 123.5^\circ C$$

T_j max being equal to $175^\circ C$ we can also use this TRANSIL in repetitive pulse operation.

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