

TRANSISTOR PROTECTION BY TRANSIL

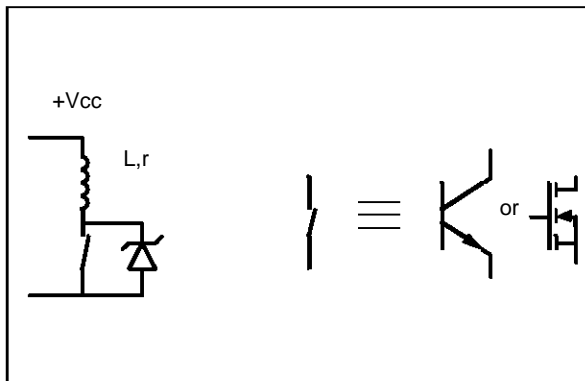
B. Rivet

1 - INTRODUCTION

In a large number of applications, we find the circuit in FIG.1 where a TRANSIL is used to protect a switch which 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.

Figure 1 : Basic Diagram

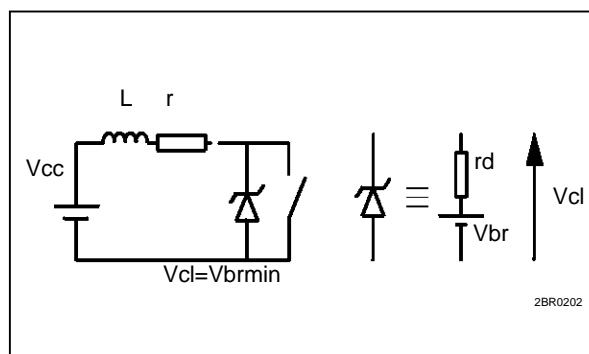


2 - CIRCUIT MODELLING

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

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

Figure 2 : Equivalent Circuit



V_{CL}	clamping voltage
V_{BR}	breakdown voltage
rd	equivalent resistance

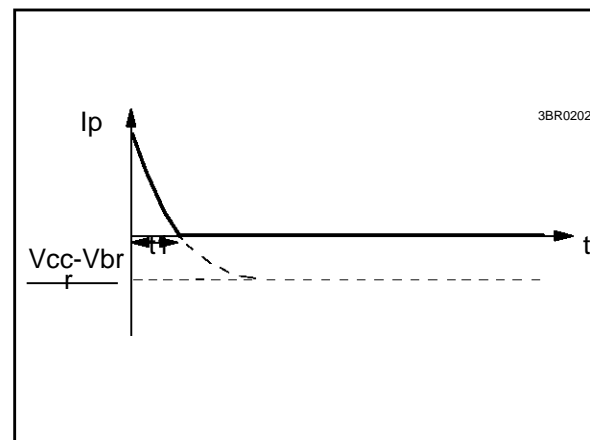
3 - CURRENT IN THE TRANSIL

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

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

I_P is the current through the coil when the transistor switches off. FIG.3 shows the current variation versus time.

Figure 3 : Current Waveform



t_1 can be calculated by

$$t_1 = -L/r \times \ln \left(I_P + \frac{V_{BR \text{ min}} - V_{CC}}{V_{BR \text{ min}} - V_{CC} + r I_P} \right)$$

4 - TRANSIL POWER DISSIPATION

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

a) 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 pulse duration t_p is calculated by the formula :

$$t_p = - (1.4L/2r) \times \ln \left(\frac{V_{BR \min} - V_{CC}}{V_{BR \min} - V_{CC} + r I_p} \right)$$

The energy in the TRANSIL can be expressed by :

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

When r tends to zero we find :

$$W = 1/2 L I_p^2 \left(\frac{V_{BR \min}}{V_{BR \min} - V_{CC}} \right)$$

b) Repetitive pulse operation

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

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

When r tends to zero we find :

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

Where F is the switching frequency.

5 - EXAMPLE OF APPLICATION

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

$$V_{CC} = 14V \quad L = 10mH \quad r = 3 \text{ Ohms} \quad I_p = 4 \text{ A}$$

TRANSIL : 1.5KE360 $V_{BR \min} = 34.2V$ (cf data sheet)

a) Single pulse

We find

$$P_p = 34.2 \times 4 = 136.8 \text{ W}$$

$$t_p = \frac{-1.4 \times 10 \times 10^{-3}}{2 \times 3} \ln \left(\frac{34.2 \times 14}{34.2 - 14 + 3 \times 4} \right)$$

$$t_p = 1.08 \text{ ms}$$

The data sheet gives $P_p \approx 1500W$ for $t_p = 1.08ms$, so the 1.5KE36P can be used in this application.

b) Repetitive pulse operation

The switching frequency is equal to 10Hz so

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

$$P = 980 \text{ mW}$$

$$R_{th} = 75^\circ\text{C/W} \text{ and } T_j \text{ max.} = 175^\circ\text{C}$$

$$\text{So } T_j = P \times R_{th} + T_{amb. \text{max.}}$$

With $T_{amb. \text{max.}} = 50^\circ\text{C}$ we find :

$$T_j = 0.98 \times 75 + 50 = 123.5^\circ\text{C} < T_j \text{ max}$$

So we can also use this TRANSIL in repetitive pulse operation.

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