TRANSISTOR PROTECTION BY TRANSIL

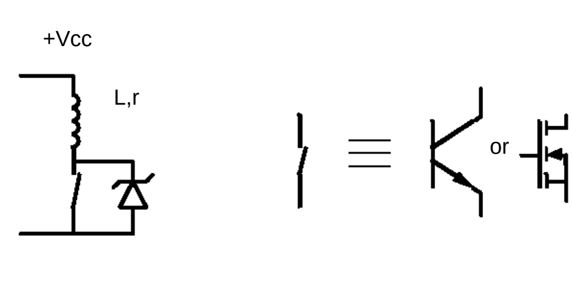
B. Rivet

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

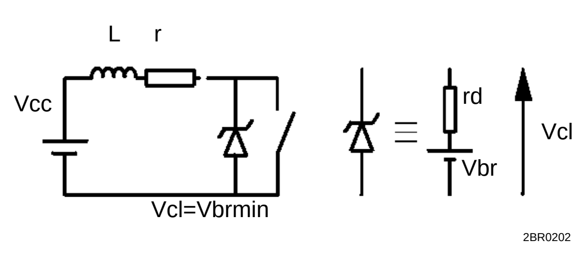


2 - CIRCUIT MODELLING

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

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

Figure 2 : Equivalent Circuit



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

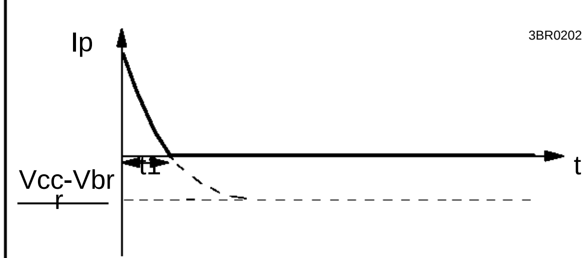
3 - CURRENT IN THE TRANSIL

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

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

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

Figure 3 : Current Waveform



t1 can be calculated by

$$t1 = -L/r \times \ln \left(I_P + \frac{V_{BR}\,\mathrm{min} - V_{CC}}{V_{BR}\,\mathrm{min} - V_{CC} + r\,I_P} \right)$$

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 Pp and the pulse current standard duration tp.

Pp 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 tp is calculated by the formula :

$$t_P = -(1.4L/2\,r) \times \ln\left(\frac{V_{BR}\min - V_{cc}}{V_{BR}\min - V_{cc} + r\,I_P}\right)$$

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 L = 10mH r = 3 Ohms I_P = 4 A

TRANSIL : 1.5KE360 VBRmin = 34.2V (cf data sheet)

a) Single pulse

We find

$$P_P = 34.2 \text{ x } 4 = 136.8\text{ W}$$

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

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

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

b) Repetitive pulse operation

The switching frequency is equal to 10Hz so

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

$$P = 980\ mW$$

Rth = 75°C/W and Tj max. = 175°C

So Tj = P x Rth + Tamb.max.

With Tamb.max. = 50°C we find :

Tj = 0.98 x 75 + 50 = 123.5°C < Tj max

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