

Thyristors - Theory, Parameters and Applications

Jurek Budek
Bedford Applications Laboratory
(Edited by M J Maytum)
Bedford Power Department

ABSTRACT

The operational characteristics of the Thyristor are derived from the basic silicon structure and its equivalent circuit. Actual device characteristics and ratings are then discussed with illustrations of the temperature and operating mode sensitivities. Based on this, design approaches are formulated for triggering, selection and control of current and voltage, switching with cooling requirements. Finally, some typical application circuits are discussed.

INTRODUCTION

The name of Thyristor is derived from the Greek word "thyra" meaning "a door". A Thyristor is a bistable semiconductor device that comprises three or more junctions and can be switched from the off state to the on state or vice versa. Switching from the off state to the on state is normally initiated by a control signal. Switch off is normally caused by the current through the Thyristor dropping below a critical level. This chapter is concerned with the two main Thyristor types called SCRs (Silicon Controlled Rectifiers - Ref. 1,1) and Triacs (Ref. 2,1, Chapter 2, Glossary, should be consulted for further information on types, terms and definitions).

The first commercial SCRs appeared in the late 1950s. They were an immediate success by providing an efficient, long life, senseless switch to replace relays, rheostats, thyatrons and such like. The SCR is a unidirectional Thyristor and so it can only be controlled in one voltage polarity. To control both polarities of the ac supply either two SCRs had to be used, connected in anti-parallel, or a single SCR inside a full wave bridge rectifier (Ref. 1, Chapter 8 - AC Phase Controlled Circuits).

In the 1960s, bidirectional Thyristors, called Triacs, were introduced. AC control was now possible with a single silicon power device. Today, through better understanding and technology, SCRs, Triacs and their derivatives are pre-eminent in the solid state control of ac power.

THEORY

BIPOLAR JUNCTION HIERARCHY

The Thyristor NPNP silicon layer structure can be considered the result of an evolution the basic PN layer junction rectifier diode, Figure 1. The following treatment of bipolar junction behaviour assumes readers are familiar with basic semiconductor theory.

Diodes

A PN junction diode has a low impedance when the P-type layer is positively (forward) voltage biased with respect to the N-type layer. The electrode connecting to the P-type layer is called the anode, symbol A, and that connecting to the N-type layer is called the cathode, symbol K. Forward conduction begins at a threshold voltage of about 0.5 V and a junction strongly in current conduction will develop voltages of 0.7 V and above. The direction of this current conduction is indicated by the arrow direction of the diode symbol.

The diode has a high impedance when the P-type layer is negatively (reverse) voltage biased with respect to the N-type layer. The maximum value of reverse voltage that the junction blocks to will depend on the junction design. Above this voltage the junction will breakdown, symbol (BR), either at the surface or internally. Internal breakdowns below about 6 V are due to the "Zener" effect and above 6 V by the "Avalanche" effect. Zener voltages decrease with increasing temperature, whilst Ava-

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