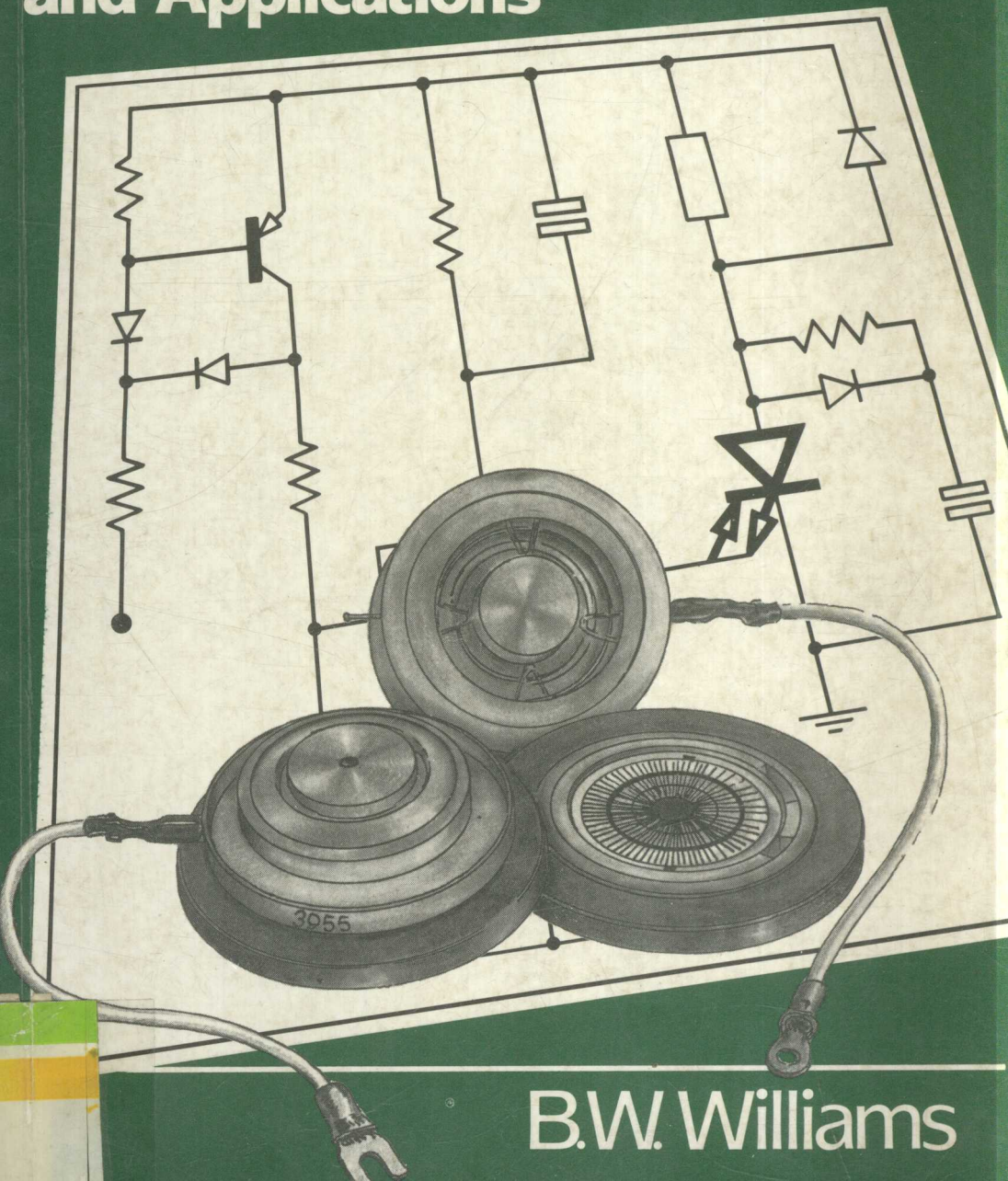
POWER ELECTRONICS

Devices, Drivers and Applications



B.W. Williams

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Power Electronics

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Preface

The objective of this book is to bridge the gap between semiconductor device theory and device application in the area of power electronics. The majority of existing books concentrate on one aspect at the expense of the other. They either analyse semiconductor physics and material aspects of devices without including any applications or, at the other end of the spectrum, they consider device applications with the device being treated as a 'black box'.

This book specifically considers high-power devices and in particular how a device's structure and construction are related to its terminal electrical and thermal characteristics. Only then, armed with an understanding of device characteristics, is it possible to select the correct device for a given application.

Emphasis is placed on the circuitry required to use power devices rather than treating them as ideal switches or considering just one device type. The structure and electrical characteristics of a device are related to its driving and protection requirements for a particular type of application.

The book is in three parts. Part 1 covers power device electrical and thermal characteristics and how they relate to a device's physical structure. Devices considered include the thyristor, gto, mosfet and bipolar transistor. Part 2 describes device driving and protection techniques and the final part gives a general selection of power electronic applications. Application areas other than those dominated by thyristors have been considered; in particular the growing area of switched-mode power supplies has been introduced.

The book gives a fundamental, yet detailed education in the art of power electronics. Since a basic knowledge of semiconductor physics and circuit techniques is assumed, it is a specialist subject book intended for university and polytechnic students, as well as for practising engineers wishing to broaden their understanding of power electronics. Non-trivial worked examples and problems have been included for the student, and each chapter has a specific reading list.

B. W. W.

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List of Symbols

a	device tolerance
A	anode
b	base
b_t	base transport factor
B_{sat}	saturation flux density
c	collector
C	capacitance
C_{ds}	drain-to-source capacitance
C_f	heat-sink correction factor
C_{gd}	gate-to-drain capacitance
C_{gs}	gate-to-source capacitance
C_o	snubber transfer capacitance
C_s	snubber capacitance
d	drain
e_o	output voltage
e_s	step input voltage
E	circuit voltage source
E_i	input voltage source
ESR	equivalent series resistance
f_m	maximum switching frequency
f_s	switching frequency
g	mosfet gate
G	thyristor gate

h	heat transfer coefficient
H_s	flux intensity at saturation
i	current
i_b	base current
i_i	input currrent
i_l	inductor current
i_o	output current
i_{rr}	reverse recovery current
i_T	thyristor anode current
I_a	prospective fault current
I_c	collector current
I_{cbo}	collector leakage current
$I_{c(max)}$	maximum allowable collector current
I_d	drain current
$I_{d(rms)}$	rms drain current
I_D	mean diode current
I_F	forward current
$I_{F(av)}$	average forward current
I_G	gate current
I_H	holding current
I_i	mean input current
I_l	leakage current
I_L	latching current
I_o	reverse leakage current
I_o	mean output current
I_p	peak let-through current
I_{rr}	peak reverse recovery current
$I_{s/b}$	second breakdown current
I_T	total current
J	junction
J_R	reverse recovery energy
k	transistor switching time ratio
K	cathode
K_{ID}	diode current form factor
K_v	voltage ripple factor
l_p	primary inductance
l_s	saturable inductance
L	inductance
L_s	linear snubber inductance

m	empirical transistor constant
M	avalanche multiplication factor
n	ratio C_s/C_o
n_i	intrinsic carrier concentration
N	turns or turns ratio
N_A	acceptor concentration
N_C	concentration
N_D	donor concentration
pd	percentage derating
P	power
P_d	average power dissipation
P_G	mean gate power
P_p	peak power
P_s	switching interval power loss
Q_G	mosfet gate charge
Q_o	diode total recovery charge
Q_R	diode reverse recovery charge
r'_b	base lateral resistance
$r(t_p)$	thermal normalising factor
R_{be}	base-to-emitter resistance
$R_{ds(on)}$	mosfet on-state resistance
R_g	gate resistance
R_L	load resistance
R_θ	thermal resistance
$R_{\theta j\text{-}c}$	thermal resistance junction-to-case
s	source
S	maximum dv/dt
SOA	safe operating area
t	time
t_a	fuse arcing time
t_c	fuse clearing time
t_d	turn-on delay time
t_D	diode conduction time
t_{fi}	current fall time
t_{fr}	diode turn-on time
t_{fv}	voltage fall time
t_m	fuse melting time
t_{off}	turn-off time

t_{on}	turn-on time
t_p	pulse width
t_q	thyristor turn-off time
t_{ri}	current rise time
t_{rr}	reverse recovery time
t_s	saturation delay time
t_T	transistor on-time
t_x	time of no conduction
T	temperature
T_a	ambient temperature
T_c	case temperature
T_j	junction temperature
T_{jmax}	maximum allowable junction temperature
T_m	main thyristor

v	voltage
$v_{be(sat)}$	base-to-emitter saturation voltage
$v_{ce(sat)}$	collector-to emitter saturation voltage
v_D	diode on-state voltage
v_o	output voltage
V	voltage
V_a	common emitter avalanche voltage
V_{ac}	ac supply voltage
V_b	junction avalanche voltage
V_{be}	base-to-emitter voltage
V_{BF}	scr forward breakover voltage
V_{BR}	scr reverse breakdown voltage
V_c	collector voltage
V_{ce}	collector-to-emitter voltage
V_D	device voltage rating
V_{ds}	drain-to-source voltage
V_{fp}	diode turn-on peak forward voltage
V_{gs}	gate-to-source voltage
V_L	line-to-line rms voltage
V_o	mean output voltage
V_{PT}	punch-through voltage
V_r	rms output voltage
V_R	reverse applied voltage
V_{RI}	ripple voltage
V_{RM}	reverse overshoot voltage
V_s	dc supply voltage
V_{TH}	mosfet threshold voltage
V_Z	Zener voltage

w	thickness
W	energy
W_t	total loss
Z	impedance
Z_θ	thermal impedance
α	current transfer ratio
α_o	α in the linear region
β	current amplification factor
β_Q	gto turn-off gain
γ	injection efficiency
δ	duty cycle
ΔT	change in temperature
λ	thermal conductance
ξ	damping factor
ξ_m	peak electric field
σ	electrical conductivity
τ	period
ϕ	$\tan^{-1}(\omega L/R)$
Φ	zero bias potential
ω	oscillation frequency
ω_o	natural oscillation frequency
$\hat{}$	peak
$\check{}$	minimum

Contents

PART 1:

DEVICES