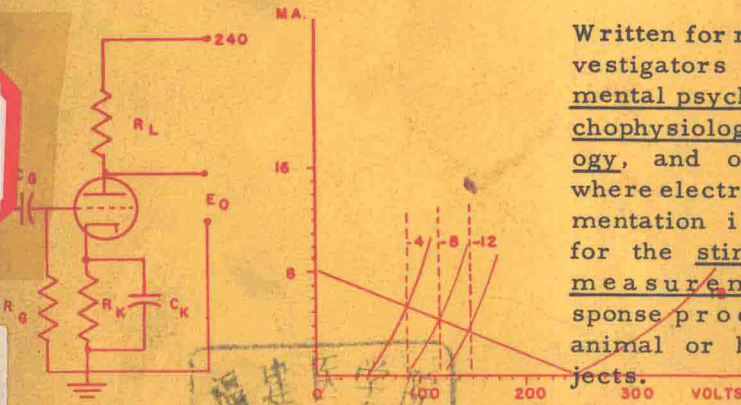


CLINTON C. BROWN, Ph.D.  
Chief, Psychophysiological Research  
Veterans Administration Hospital  
Perry Point, Maryland

RAYFORD T. SAUCER, Ph.D.  
Research Associate  
Psychophysiological Laboratory  
Veterans Administration Hospital  
Perry Point, Maryland

# Electronic Instrumentation for the BEHAVIORAL SCIENCES

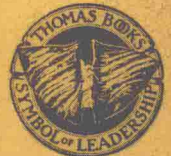
A simplified  
presentation  
of basic  
electronic  
theory  
required for  
instrumentation  
problems.



Written for research investigators in experimental psychiatry, psychophysiology, physiology, and other fields where electronic instrumentation is required for the stimulation or measurement of response processes in animal or human subjects.

福建医学  
图书馆藏书

American Lecture Series®



# ELECTRONIC INSTRUMENTATION FOR THE BEHAVIORAL SCIENCES

*By*

CLINTON C. BROWN. Ph.D.

*Chief, Psychophysiological Research  
Veterans Administration Hospital, Perry Point, Maryland*

RAYFORD T. SAUCER, Ph.D.

*Research Associate  
Psychophysiological Laboratory  
Veterans Administration Hospital, Perry Point, Maryland*



CHARLES C THOMAS • PUBLISHER

*Springfield • Illinois • U.S.A.*

CHARLES C THOMAS • PUBLISHER  
BANNERSTONE HOUSE  
301-327 East Lawrence Avenue, Springfield, Illinois, U.S.A.

*Published simultaneously in the British Commonwealth of Nations by*  
BLACKWELL SCIENTIFIC PUBLICATIONS, LTD., OXFORD, ENGLAND

*Published simultaneously in Canada by*  
THE RYERSON PRESS, TORONTO

This book is protected by copyright. No part  
of it may be reproduced in any manner with-  
out written permission from the publisher.

*Copyright 1958, by* CHARLES C THOMAS • PUBLISHER

Library of Congress Catalog Card Number: 57-12537

*Printed in the United States of America*

**ELECTRONIC INSTRUMENTATION  
FOR THE  
BEHAVIORAL SCIENCES**

*Publication Number 320*

AMERICAN LECTURE SERIES ®

*A Monograph in*  
The BANNERSTONE DIVISION of  
AMERICAN LECTURES IN OBJECTIVE  
PSYCHIATRY

*Edited by*

W. HORSLEY GANTT, M.D.  
*Phipps Psychiatric Clinic*  
*The Johns Hopkins Hospital*  
*Baltimore, Maryland*

## FOREWORD

W. HORSLEY GANTT



A knowledge of instruments is not only a keystone in research, but in our age, the complexity and diversity of instruments requires highly specialized knowledge of physics as well as biology. These authors are qualified in both respects. Dr. Clinton Brown has been one of my collaborators in psychopathological investigations of both patients and animals. The authors have a thorough understanding of the needs of research and a theoretical and also a practical knowledge of the necessary instruments. It is with great satisfaction that I have persuaded Dr. Clinton Brown to present the results of his experience with apparatus and instruments used in psychobiological research, a task in which he has solicited the useful collaboration of Dr. Saucer.

# CONTENTS

	<i>Page</i>
<i>Foreword</i> .....	v
<i>List of Figures</i> .....	ix
<i>Chapter</i>	
1. Instruments and Behavior .....	3
1.1 .....	3
1.2 Research from Instruments .....	4
1.3 Purpose of the Text .....	5
2. Introduction to Electronics .....	7
2.1 Atomic Architecture .....	7
2.2 Basic Electrical Units .....	8
2.3 Fractional Electrical Units .....	9
2.4 Capacitance .....	9
2.5 Direct and Alternating Currents .....	10
2.6 Electromagnetism and Inductance .....	12
2.7 Inductance .....	13
2.8 Impedance .....	14
2.9 Capacitive Reactance .....	15
2.10 Summary of Impedance .....	16
2.11 Load Match and Power Transfer .....	17
2.12 Circuit Algebra .....	17
2.13 Voltage Dividers .....	18
3. Vacuum Tubes .....	20
3.1 Electron Flow in a Vacuum .....	20
3.2 Thermionic Emission .....	20
3.3 Filaments .....	21
3.4 Filament Voltages .....	21

<i>Chapter</i>	<i>Page</i>
3.5 Diode Tubes .....	22
3.6 Triode Tubes .....	22
3.7 Amplification Factor .....	23
3.8 Plate Resistance .....	24
3.9 Transconductance .....	24
3.10 Bias Voltage .....	24
3.11 Fixed Bias .....	25
3.12 Gridleak Bias .....	25
3.13 Cathode Bias .....	26
3.14 Load Lines and Load Resistors .....	26
3.15 Tetrode Tubes .....	28
3.16 Pentode Tubes .....	28
3.17 Beam Power Tubes .....	29
3.18 Gas Diodes .....	29
3.19 Thyratrons .....	29
3.20 Photoelectric Emission .....	30
3.21 Multipurpose Tubes .....	30
3.22 Low Potential Tubes .....	31
3.23 General Considerations .....	31
4. Power Supplies .....	32
4.1 Operating Potentials .....	32
4.2 Vacuum Tube Rectifiers .....	32
4.3 Filter Circuits .....	33
4.4 Regulator Tubes .....	34
4.5 Electronic Voltage Regulation .....	35
4.6 Metallic Rectifier .....	37
4.7 Power Transformers .....	38
4.8 Filter Condensers .....	39
4.9 Dry Cells .....	40
4.10 Vibrator Power Supplies .....	41
4.11 Other Power Supplies .....	42



<i>Chapter</i>	<i>Page</i>
4.12 Other Safety Precautions .....	43
5. Amplifiers .....	44
5.1 Principles .....	44
5.2 Filters .....	44
5.3 Low Pass Filters .....	46
5.4 High Pass Filters .....	46
5.5 Bandpass Filters .....	47
5.6 Applications .....	48
5.7 RC Coupling Networks .....	49
5.8 Push-Pull Amplifiers .....	50
5.9 Phase Inverters .....	52
5.10 Direct Coupled Amplifiers .....	53
5.11 Power Amplifiers .....	56
5.12 General Purpose Amplifiers .....	56
5.13 Cathode Followers .....	57
6. Oscillators .....	60
6.1 Feedback Loops .....	60
6.2 Transformer Oscillators .....	60
6.3 RC Phase Shift Networks .....	61
6.4 Wein Bridge Oscillators .....	62
6.5 Beat Frequency Oscillators .....	63
6.6 Other Commercial Oscillators .....	64
7. Timing Circuits .....	65
7.1 Timing Operators .....	65
7.2 Timing in the Behavioral Sciences .....	65
7.3 Electronic Time Bases .....	66
7.4 RC Charges .....	66
7.5 RC Networks as Timing Devices .....	67
7.6 Thyatron Oscillators .....	68
7.7 Thyatron Timer Circuit .....	69
7.8 A Bootstrap Circuit .....	70

<i>Chapter</i>	<i>Page</i>
7.9 Phantastron Circuit .....	71
7.10 Multivibrators .....	73
7.11 Stabilizing the Multivibrator .....	75
7.12 Flipflop Circuits .....	75
8. Timed Sequences and Switching Circuits .....	81
8.1 Introduction .....	81
8.2 Switches .....	81
8.3 Relay Types .....	83
8.4 Relay Applications .....	85
8.5 Relay Algebra .....	88
9. Stimulus Generators and Input Transducers .....	92
9.1 Definitions .....	92
9.2 Requisites of Stimulus Generators .....	93
9.3 Auditory Stimuli .....	94
9.4 Visual Stimuli .....	96
9.5 Vestibular Stimulation .....	99
9.6 Tactual Stimulation .....	99
9.7 Painful Stimulation .....	99
9.8 Olfactory and Gustatory Stimulation .....	104
9.9 Input Transducers .....	104
9.10 Special Cardiac Transducers .....	105
9.11 Blood Pressure Transducers .....	107
9.12 Plethysmographic Transducers .....	108
9.13 Respiration Transducers .....	109
9.14 Heat Sensitive Transducers .....	111
9.15 pH Transducers .....	112
9.16 Motion Transducers .....	112
9.17 Eyeblink Transducers .....	113
9.18 Muscle Action Transducers .....	113
9.19 Output Transducers: The Display and Recording of Signals .....	113

<i>Chapter</i>	<i>Page</i>
9.20 Meters and Recording Pen Motors . . . . .	114
9.21 Cathode Ray Tube Indicators . . . . .	115
10. Test Instruments . . . . .	119
10.1 Introduction . . . . .	119
10.2 D'Arsonval Meters . . . . .	119
10.3 Meter Multipliers . . . . .	121
10.4 Meter Shunts . . . . .	122
10.5 Ohmmeters . . . . .	123
10.6 Multimeters . . . . .	123
10.7 Voltohmmeters . . . . .	124
10.8 AC Voltmeters . . . . .	125
10.9 Readout Meters . . . . .	125
10.10 Oscilloscopes . . . . .	125
10.11 Summary . . . . .	126
11. Transistor Theory and Application . . . . .	128
11.1 Applications . . . . .	128
11.2 Transistor Theory . . . . .	129
11.3 NPN and PNP Junctions . . . . .	130
11.4 Other Transistor Types . . . . .	132
11.5 Electrical Characteristics . . . . .	134
11.6 Transistor Amplifier Configuration . . . . .	134
11.7 Contrasts Between Tube and Transistor . . . . .	134
11.8 Representative Transistor Circuits . . . . .	136
11.9 Transistor Trigger . . . . .	136
11.10 Pushpull Amplifier . . . . .	137
11.11 Cascaded Amplifiers . . . . .	138
11.12 Transistor Timer . . . . .	138
11.13 Transistor Multivibrator . . . . .	139
11.14 Transistor Oscillators . . . . .	140
11.15 Cortical Stimulator . . . . .	141
11.16 Audio Amplifiers . . . . .	142

<i>Chapter</i>	<i>Page</i>
12. The Laboratory Workshop .....	143
12.1 Introduction .....	143
12.2 Power Tools .....	143
12.3 Miscellaneous Mechanical Tools .....	144
12.4 Miscellaneous Electrical Tools .....	145
12.5 Component Stocks .....	145
12.6 Test Construction .....	146
12.7 Chassis Layout .....	147
12.8 Wiring .....	148
 <i>Appendix</i>	
I References .....	149
II Selected Periodicals .....	152
III Commercial Sources of Instruments and Components .....	153
IV Preferred Tube Types .....	156
1. Rectifiers .....	156
2. Diodes .....	156
3. Triodes .....	156
4. Pentodes .....	157
5. Beam Power Tubes .....	157
6. Regulators, VR Type .....	157
7. Multigrid Amplifiers .....	158
8. Thyratrons .....	158
Index .....	159

## LIST OF ILLUSTRATIONS

<i>Figure</i>	<i>Page</i>
2.1 .....	18
3.1 .....	22
3.2 .....	26
4.1 .....	32
4.2 .....	33
4.3 .....	34
4.4 .....	35
4.5 .....	36
4.6 .....	37
4.7 .....	42
5.1 .....	45
5.2 .....	46
5.3 .....	47
5.4 .....	47
5.5 .....	49
5.6 .....	51
5.7 .....	53
5.8 .....	54
5.9 .....	58
6.1 .....	62
6.2 .....	63
7.1 .....	67
7.2 .....	67
7.3 .....	68
7.4 .....	69
7.5 .....	71
7.6 .....	72

<i>Figure</i>	<i>Page</i>
7.7 .....	74
7.8 .....	76
7.9 .....	77
8.1 .....	85
8.2 .....	87
8.3 .....	88
8.4 .....	89
8.5 .....	89
8.6 .....	90
8.7 .....	90
9.1 .....	97
9.2 .....	98
9.3 .....	102
9.4 .....	103
9.5 .....	108
9.6 .....	110
9.7 .....	112
9.8 .....	116
10.1 .....	120
10.2 .....	122
10.3 .....	123
10.4 .....	124
11.1 .....	131
11.2 .....	135
11.3 .....	136
11.4 .....	137
11.5 .....	138
11.6 .....	139
11.7 .....	140
11.8 .....	141
11.9 .....	141

**ELECTRONIC INSTRUMENTATION  
FOR THE  
BEHAVIORAL SCIENCES**





## INSTRUMENTS AND BEHAVIOR

1.1. Some of the requisites for productive investigation in the behavioral sciences have undergone a drastic evolution in the last several decades. Fortunately, insight, skill and application are still the best of the primary tools of the researcher. Yet where it was once possible to begin an investigation with simple equipment (borrowed for the most part from classical physics), a speculative frame of mind and sound logic, it is now often necessary to expend a sizeable portion of research funds upon elaborate, costly and highly specialized equipment.

And this is not the total of expenditures, since it is most feasible to employ specialists to maintain and repair these research instruments.

Despite the advantages of increased sensitivity and accuracy of measurement provided by instrumentation, it may sometimes appear to the harassed investigator that his modern equipment represents a mixed blessing. This is particularly true since many researchers display basic prejudices against "gadgets," possibly based upon a lack of knowledge of the engineering principles involved.

Yet the need for complex instrumentation has arisen from a number of real sources.

First, much of the procedurally simple, pioneering type of investigation of more obvious behavior has already been performed. This does not imply that there are no new frontiers of investigation but only that there are relatively