

# A History of Impedance Measurements

by Henry P. Hall

|  |    |
|--|----|
| Preface  | 2  |
| Scope  | 2  |
| Acknowledgements   | 2  |
| <br>   |    |
| Part I. The Early Experimenters 1775-1915                  | 3  |
| 1.1 Earliest Measurements, Dc Resistance                   | 3  |
| 1.2 Dc to Ac, Capacitance and Inductance Measurements      | 6  |
| 1.3 An Abundance of Bridges                                | 10 |
| References, Part I   | 14 |
| <br>   |    |
| Part II. The First Commercial Instruments 1900-1945        | 16 |
| 2.1 Comment: Putting it All Together                       | 16 |
| 2.2 Early Dc Bridges                                       | 16 |
| 2.3 Other Early Dc Instruments                             | 20 |
| 2.4 Early Ac Bridges                                       | 21 |
| 2.5 Other Early Ac Instruments                             | 25 |
| References Part II   | 26 |
| <br>   |    |
| Part III. Electronics Comes of Age 1946-1965               | 28 |
| 3.1 Comment: The Post-War Boom                             | 28 |
| 3.2 General Purpose, "RLC" or "Universal" Bridges          | 28 |
| 3.3 Dc Bridges   | 30 |
| 3.4 Precision Ac Bridges: The Transformer Ratio-Arm Bridge | 32 |
| 3.5 RF Bridges   | 37 |
| 3.6 Special Purpose Bridges                                | 38 |
| 3,7 Impedance Meters                                       | 39 |
| 3.8 Impedance Comparators                                  | 40 |
| 3.9 Electronics in Instruments                             | 42 |
| References Part III  | 44 |
| <br>   |    |
| Part IV. The Digital Era 1966-Present                      | 47 |
| 4.1 Comment: Measurements in the Digital Age               | 47 |
| 4.2 Digital Dc Meters                                      | 47 |
| 4.3 Ac Digital Meters                                      | 48 |
| 4.4 Automatic Ac Bridges                                   | 50 |
| 4.5 Computer-Bridge Systems                                | 52 |
| 4.6 Computers in Meters and Bridges                        | 52 |
| 4.7 Computing Impedance Meters                             | 53 |
| 4.8 Instruments in Use Today                               | 55 |
| 4.9 A Long Way from Ohm                                    | 57 |
| References Part IV   | 59 |
| <br>   |    |
| Appendices:  |    |
| A. A Transformer Equivalent Circuit                        | 60 |
| B. LRC or Universal Bridges                                | 61 |
| C. Microprocessor-Base Impedance Meters                    | 62 |