PB 161558

NBS

Technical Note No. 57

Boulder Laboratories

VARIABLE CAPACITOR CALIBRATION WITH AN INDUCTIVE VOLTAGE DIVIDER BRIDGE

BY THOMAS L. ZAPF

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers. These papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($1.50), available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

NATIONAL BUREAU OF STANDARDS

Technical Note

57

May, 1960

VARIABLE CAPACITOR CALIBRATION WITH AN INDUCTIVE VOLTAGE DIVIDER BRIDGE

by

Thomas L. Zapf

NBS Technical Notes are designed to supplement the Bureau's regular publications program. They provide a means for making available scientific data that are of transient or limited interest. Technical Notes may be listed or referred to in the open literature. They are for sale by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

DISTRIBUTED BY

UNITED STATES DEPARTMENT OF COMMERCE

OFFICE OF TECHNICAL SERVICES

WASHINGTON 25, D. C.

Price $ .50

CONTENTS

LIST OF ILLUSTRATIONS

VARIABLE CAPACITOR CALIBRATION WITH AN INDUCTIVE VOLTAGE DIVIDER BRIDGE

Thomas L. Zapf

ABSTRACT

The use of an inductive voltage divider bridge for the calibration of three-terminal and two-terminal variable air capacitors is discussed.

VARIABLE CAPACITOR CALIBRATION WITH AN INDUCTIVE VOLTAGE DIVIDER BRIDGE

by

Thomas L. Zapf

1. INTRODUCTION

The accurate calibration of variable air capacitors can be accomplished by several methods, one of which has been described as a step-up or step-substitution method (1). Another method, that is particularly useful for the calibration of three-terminal capacitors, is presented in this paper.

Very simple inductive ratio arm bridges may be assembled for the calibration of direct capacitance of three-terminal capacitors or capacitance differences of two-terminal variable air capacitors using fixed three-terminal capacitors as reference standards.

2. EQUIPMENT

Commercially available inductive voltage dividers can be used as inductively-coupled ratio arms of a capacitance bridge. The accuracy of ratio of the arms thus formed often far exceeds that needed for the calibration of variable air capacitors, even if the nominal ratio is used without correction.

Because of the inherent freedom from variations of their direct capacitance,it is desirable to use three-terminal capacitors (now commercially available) as fixed standards, particularly with bridges having inductively-coupled ratio arms. The stray capacitances to ground are then across either the detector or the ratio arms. A small capacitance across the detector generally does no

more than reduce the sensitivity, and the effect on accuracy of loading the closely coupled ratio arms, which have very small equivalent series impedance, is negligible.

3. THE BRIDGE CIRCUIT

Figure 1 shows an oscillator-amplifier power supply connected to the extremities of an inductive voltage divider, to one terminal of the fixed standard capacitor, C_s, and to one terminal of the variable capacitor under test, C. The other terminal of each of the capacitors is connected to one input terminal of a sensitive ac detector by means of well-shielded cable with shielded connectors. The shields of these cables, the other terminal of the detector, and the variable tap on the inductive voltage divider are connected together and to ground. The variable capacitor is set to the calibration point and the inductive voltage divider adjusted until the bridge is balanced. If A is the reading of the inductive voltage divider, $C = \left(\frac{1}{A} - 1\right) C_s$. For best precision it is suggested that C_s be approximately equal to the maximum capacitance of C.

In Figure 2, a modification is shown in which the inductive voltage divider is grounded at a fixed tap, A_T, by means of a separate wire connected to one contact of the first decade switch. When the bridge is balanced, $C = \left(\frac{A}{A_T} - 1\right) C_s$, and if $A_T = 0.5$, $C = 2(A - 0.5)C_s$. This particular modification is rather convenient for routine calibrations because computations are simplified.

If good quality air capacitors are used in the above bridge circuit, it may not be necessary to provide for the conductance balance of the circuit. If better resolution is desirable, however, a small adjustable resistor of several hundred ohms or less may be placed

in series with one or the other (as needed) of the capacitors in the unshielded leads to the inductive voltage divider as shown in Figure 2. Resistors, so placed, may permit a considerable improvement in the precision of the balance.

It should be evident that one three-terminal variable capacitor, set to a known capacitance by means of a larger fixed standard, serves excellently as a temporary standard to extend measurements to smaller values. Several orders of magnitude can be covered by this means. If extension of measurements to larger capacitance is contemplated, consideration must be given to the effect of inductance in the leads and in the resistor mentioned above.

4. TWO-TERMINAL CAPACITANCE MEASUREMENTS

The electrical connections to a single-range, two-terminal, variable air capacitor are shown in Figure 3. It is evident that the case of the capacitor is not grounded. The admittance from case to ground is merely a load on the inductive voltage divider and is generally of no consequence. If the voltage applied to the extremities is kept low, there is no danger to the operator, but to avoid small but disconcerting changes in the balance of the bridge resulting from changing capacitance at the terminals, the observer should avoid touching the case of the capacitor during the balancing operation, and should keep away from the terminals. The uncertainties of capacitance at the terminals of two-terminal capacitors is discussed in detail in reference (2). If the unused terminal of a dual-range, two-terminal,variable air capacitor is normally left unconnected, then, when calibrating the capacitor by this method it will be necessary to place a guard cap over, but not touching, the unused terminal. The guard cap must be electrically connected to the case of the

capacitor as shown in Figure 4. Capacitance differences corresponding to two settings of a variable air capacitor can be measured with excellent accuracy by this method.

5. CONCLUSION

Inductive voltage dividers can be used as ratio arms of a transformer capacitance bridge for two-terminal capacitance difference measurements as well as three-terminal capacitance measurements.

REFERENCES

(1) T. L. Zapf, Capacitor calibration by step-up methods, J. Res. NBS. 64C, 75 (1960)

(2) J. F. Hersh, A close look at connection errors in capacitance measurements, General Radio Experimenter. 33, (No. 7), 3 (1959)

The two following papers contain references to prior literature on bridges having inductively-coupled ratio arms.

(3) A. M. Thomson, The precise measurement of small capacitances, IRE Trans. on Instrumentation. I-7, 245 (1958)

(4) M. C. McGregor, J. F. Hersh, R. D. Cutkosky, F. K. Harris, and F. R. Kotter, New apparatus at the National Bureau of Standards for absolute capacitance measurement, IRE Trans. on Instrumentation. I-7, 253 (1958)

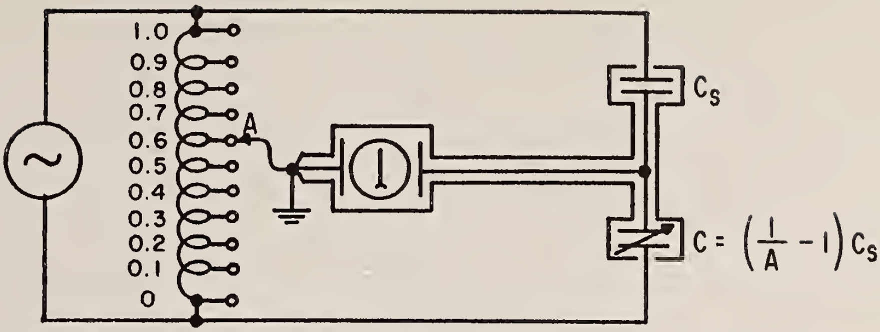

Figure 1. A simple transformer capacitance bridge for direct capacitance measurements.

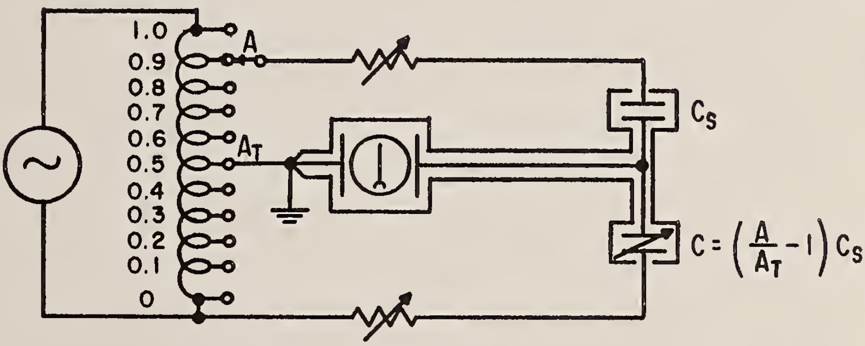

Figure 2. A modification of the bridge shown in Figure 1.

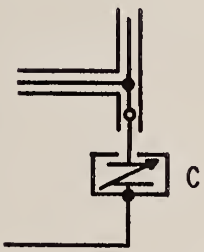

Figure 3. Connections for two-terminal capacitance measurements.

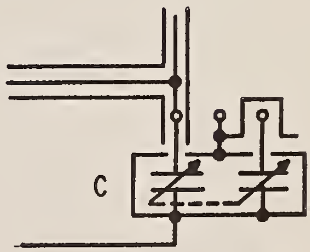

Figure 4. Connections to a dual-range, two-terminal variable air capacitor showing guard cap over unused terminal.

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

• Office of Basic Instrumentation. • Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

NBS