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A Clip-On DC Milliammeter For Measuring Tube And Transistor Circuit Currents

IN typical electronics work direct currents are ordinarily measured either by measuring the current directly with a moving-coil type current meter or by measuring the voltage drop across a known resistance in the circuit. Although each of these methods has a long tradition, each also has substantial disadvantages. In the case of the indirect method with a voltmeter, the measurements are most often made across resistances having tolerances of 10% to 20% so that a minimum ambiguity of this same amount also exists in the current value obtained. Frequently, this ambiguity leads to selection of non-optimum component values with later difficulties. In the case of the direct method with a moving-coil instrument, the circuit must be opened and the current meter connected therein. This is an inconvenience that in practice often results in omission of the measurement with subsequent erroneous deduction and wasted effort. Additionally, in the continually-growing field of low-impedance circuits, where the current parameter assumes greater importance as in transistor work, the resistance of the moving-coil instrument is sometimes intolerable.

SEE ALSO:
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enlarged, p. 4

A new and much-easier-to-use current-measuring instrument that overcomes the foregoing objections has been developed in the form of a clip-on dc milliammeter which, as far as is known, is the first instrument of its type to be brought to production status. It makes the measurement of direct currents in low- as well as high-impedance circuits as easy as a measurement of voltage and at the same time covers the whole range of currents encountered in such work—from a fraction of a milliampere to 1 ampere in six ranges.

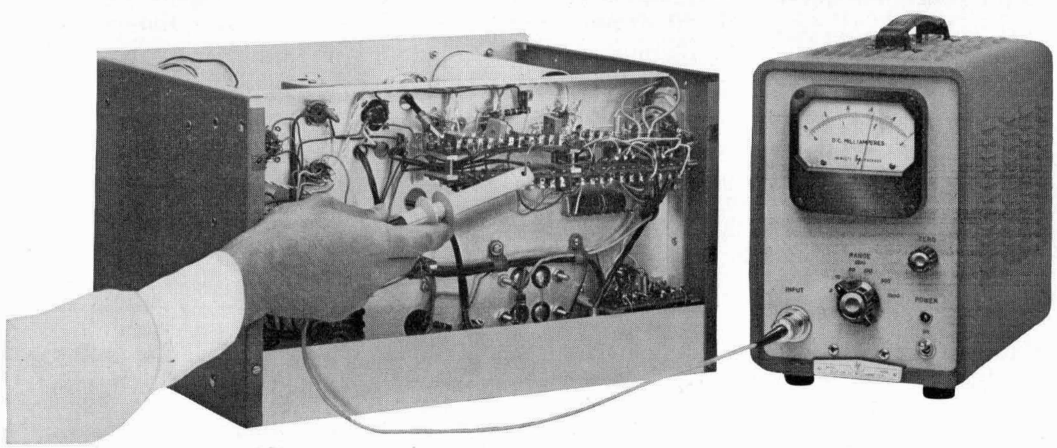


Fig. 1. New -hp- Model 428A Clip-On DC Milliammeter measures dc currents merely by clipping probe around conductor. Current range is from a fraction of a milliampere to 1 ampere. Probe jaws are operated by flanges on probe body as shown in Fig. 3.

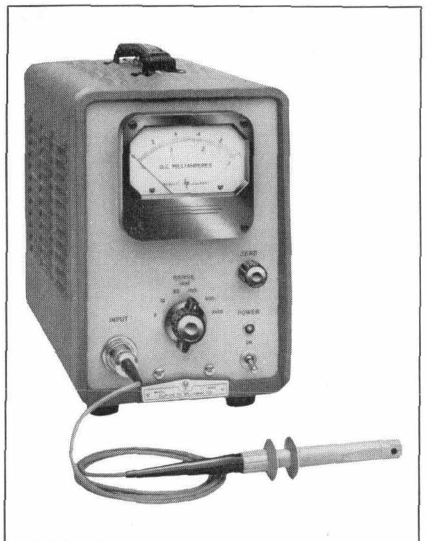


Fig. 2. -hp- *Model 428A Clip-On DC Milliammeter measures current in six 3:1 ranges from 3 ma full scale to 1 ampere full scale. Probe attaches to cabinet by 4' cable.*

Further, and especially valuable in the transistor field, it introduces no dc loading into the circuit being measured. Currents in low-impedance transistor circuits can thus be measured without disturbing static operating conditions. Also, the presence of alternating currents normally causes no error in the direct-current readings.

The instrument consists of a clip-on probe with associated electronic circuitry and indicating meter located in a small cabinet. The probe has been constructed in the -*hp*- penholder style in which flanges on the probe body open a set of split jaws for clipping around the conductor to be measured (Fig. 3). In typical practice the instrument can measure dc current in nearly any instance where a ½-inch length of conductor is available for the probe to clip around. Measurements can be made adjacent to a tube socket terminal, on transistor leads, on a conductor of a laced cable, and even on small composition resistors. At the same time remarkably few measuring precautions are required. Mainly, it is merely necessary to insure that the probe jaws are closed and are free of gap-causing particles, a condition which is easy to test for, since improper closure is indicated by a large earth's-field reading on the low range.

ELECTRICAL OPERATION

The new milliammeter operates by sensing the strength of the magnetic field produced by the current being measured. Since this sensing extracts no energy from the field, the milliammeter has the unusual property that it introduces no resistance (and very little inductance—less than 0.5 microhenry) into the circuit being measured. Freedom from loading is, of course, always desirable in a measuring instrument, but in transistor work where low-impedance circuits are common this property is especially valuable.

In some uses such as searching for shorts it is desirable to know the direction of current flow. The sensing elements in the probe are such that current direction can be determined, and the probe itself is marked with an arrow that shows current direction for an upscale reading. Connecting the probe on the conductor in the reverse orientation causes the meter pointer to move downscale but has no damaging effect on the instrument.

The probe contains a specially-developed magnetic amplifier which provides an ac output proportional to the magnetizing force produced by the measured dc current. The ac output is amplified and applied to a phase-sensitive detector whose output in turn feeds an indicating meter. The overall system including the magnetic amplifier is stabilized with 40 db of feedback for good long-time performance.

The ac signals produced by the magnetic amplifier in the probe occur at low levels so that the amplitude of the signal coupled into the measured circuit is slight. No specification for this amplitude has as yet been firmly established for production instruments but experience to date indicates it will be about 1/100 volt peak. The signal frequency has been selected to lie at a little-used region—40 kc—so that only rarely will the operation of the instrument be affected by the presence of this frequency and its harmonics in a circuit being measured. The presence of a frequency within about 20 cycles of 40 kc and its harmonics in the measured circuit will be indicated by a beat in the meter reading.

HIGHER SENSITIVITIES

On the instrument's most sensitive range (3 milliamperes full scale), readings can be made down to a minor division (0.1 ma) or so from the bottom of the scale, since the ultimate limitation of Barkhausen noise causes less than a half division reading at the bottom of the scale. In many cases, however, even higher sensitivities can be obtained by looping the conductor being measured through the probe two or more times to increase the effective magnetizing force of the current. Scale readings should then be divided by a factor equal to the number of turns made in the conductor.

A SPECIAL NOTE TO READERS

Because of the substantial convenience and savings of time that the new dc clip-on milliammeter promises where measurements of current are of interest, the accompanying information is being made available somewhat earlier than usual, since first full factory production is scheduled at five months. This step has been taken so that those to whom the instrument is potentially of value may have an opportunity to consider it in relation to their own programs. In production situations, for example, where speed and convenience of measurement are always important, it may be advantageous to substitute measurements of current in some places where indirect methods are presently used in test and checkout procedures or to inaugurate suitable new procedures for planned new equipment, both of which make advance programming a consideration.

The instrument may be seen at the WESCON trade show in Los Angeles from August 19 to 22. Somewhat later -*hp*- representatives will have instruments available for demonstration purposes. The instrument will also be demonstrated at other exhibits during the fall including the *Instrument and Automation Conference and Exhibit* in Philadelphia and the *National Electronics Conference* in Chicago.

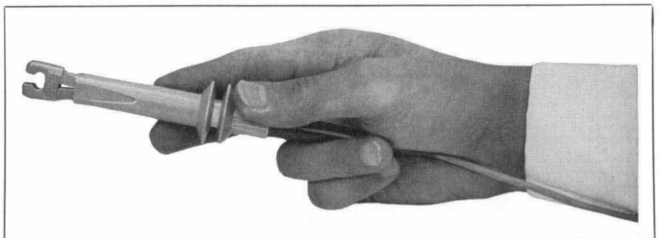


Fig. 3. *Probe jaws are opened by flanges on probe body. Spring return closes jaws when flanges are released.*

The sensitivity can be increased in this manner until reverse-coupled voltage becomes a limiting factor. Each additional turn will add the amount of reverse-coupled voltage described above for one turn. Even here, though, it should be noted that measurements can often be made at points in the circuit where a circuit capacitor will bypass the voltage, which is essentially 40 kc in composition.

HOMOGENEOUS AND NONHOMOGENEOUS EXTERNAL FIELDS

In order to make the instrument suitable for measuring small currents, considerable care has been taken to minimize the effects of external fields on the probe elements. The effect of external homogeneous fields is minimized by a balanced arrangement for the probe elements. In practice, the chief homogeneous field to be dealt with is the earth's field, but it is interesting to note that from the standpoint of small-current measurement the earth's field is relatively very strong. One way of illustrating this point is to note that the earth's field is roughly the same as the magnetizing force produced in the probe magnetic circuit by a conductor carrying 1 ampere.

The construction of the probe is such that no effects can be noticed from the earth's field other than on the most sensitive range. With the instrument set to this range, the most adverse changes in probe orientation will cause a shift in zero reading of less than ±1 minor division, an effect which can then be compensated for any one orientation by adjustment of the zero control.

A high degree of shielding against nonhomogeneous fields is also provided so that measurements are essentially free from effects from currents in nearby conductors. Typically, a current of 1 ampere flowing in a conductor so close that it is touching the probe will produce an effect amounting to only about 3% of the most sensitive range, while if the conductor is 1 inch away the effect is scarcely perceptible.

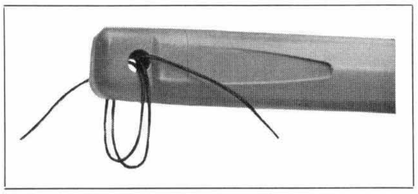


Fig. 4. *Measurement sensitivity can be increased by looping conductor through probe one or more times to increase effective magnetizing force of measured current. Probe accepts single conductors of up to $\frac{3}{16}$-inch overall diameter.*

ACCURACY

Rated accuracy for the instrument is ±3% of full scale ±0.1 milliampere. This is an overall rating that includes the effect of operating the instrument from line voltages up to ±10% from a 115-volt center value, of meter movement tolerance, of temperature over normal room ranges, etc. The rating also applies when ac currents exist in the circuit being measured as long as their peak value does not exceed the full-scale value of the range used, and as long as they are not near 40 kc, as discussed earlier.

DEGAUSSING

The magnetic sensing elements in the probe are sufficiently free of remanence or residual induction effects that residual readings are not obtained in the normal course of measurements. If, however, large overloads of many amperes are applied such as from shorts in a measured circuit or rapid discharge of a capacitor, residual readings will result, and for this contingency a degausser is included in the instrument. The degausser is activated by a momentary-contact switch, which in use is manually held closed while the probe is withdrawn from the degausser aperture. On cabinet style instruments the degausser is located at the back of the cabinet and on rack instruments at the front.

GENERAL APPLICATIONS

A note is also in order concerning the general usefulness of the instrument since, although it was developed with low-impedance work principally in mind, it has turned out to be extremely useful in the general course of electronics work in higher-impedance circuits as well. It is useful for searching out shorts, checking tube electrode currents, checking power supply currents, and simply measuring currents for any number of purposes.

It has also been found very useful in production work where, with some advance programming of data for technicians, it becomes valuable for checking currents both in insuring proper operation of production equipment and in trouble-shooting.

—*Arndt Bergh, Charles O. Forge,* and *George S. Kan*

TENTATIVE SPECIFICATIONS
-hp-
MODEL 428A
CLIP-ON DC MILLIAMMETER

Current Range: Less than 0.3 milliampere to 1 ampere in 6 ranges with full-scale values of 3 ma, 10 ma, 30 ma, 100 ma, 300 ma, 1 ampere.

Accuracy: With line voltages of 115 volts ±10%, overall accuracy is ±3% ±0.1 ma. Errors include effects of earth's magnetic field, repeatability of probe closure, and noise and normal ambient room temperature ranges.

Inductance Introduced by Probe: Probe will cause less than 0.5 μh of inductance to be introduced into circuit being measured.

Effects of AC in Circuit being Measured: AC with a peak value less than 100% of full scale will have no effect on DC reading unless its frequency is within a few cycles of 40 kc and its harmonics.

Effects of Impedance of Circuit Being Measured: No errors will result if impedance of circuit being measured is 0.1 ohm or more at 40 kc.

Power Requirements: 115/230 volts, ±10%, 100 watts.

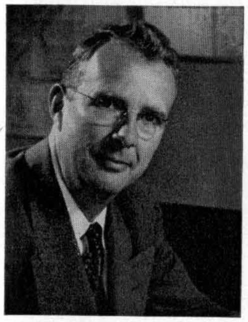
Dimensions: Cabinet mount: 7½" wide, 11½" high, 14¼" deep; rack mount: 19" wide, 7" high, 12¼" deep.

Weight: Cabinet mount: 19 lbs. net, 24 lbs. shipping; rack mount: 24 lbs. net, 35 lbs. shipping.

Price: Model 428A cabinet mount: $475.00 f.o.b. Palo Alto, Calif. Model 428AR rack mount: $480.00 f.o.b. Palo Alto, Calif.

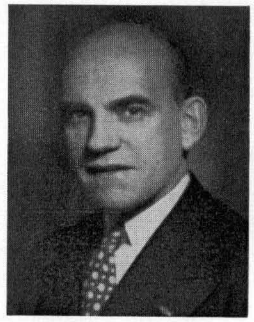
Data subject to change without notice

-*hp*- BOARD OF DIRECTORS ENLARGED

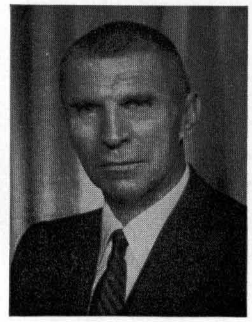


L. W. Alvarez

C. R. Blyth



H. H. Buttner



T. P. Pike

F. E. Terman

The -*hp*- Board of Directors has recently been enlarged by the election thereto of Dr. Luis W. Alvarez, Charles R. Blyth, Harold H. Buttner, Thomas P. Pike, and Dr. Frederick E. Terman. These men bring a broad technical and administrative background to serve in policy guidance of -*hp*-'s expanding affairs.

Dr. Alvarez is assistant director of the University of Caifornia Radiation Laboratory and is well known to the engineering profession for his major contributions in both the physical and electronic fields. Besides being responsible for development of early warning microwave radar, a high-altitude bombing system, and GCA, he is co-discoverer of the "east-west" effect in cosmic rays, of Tritium and He^3, and jointly and singly of other important physical processes. He is also responsible for the design and construction of the Berkeley 40-foot proton linear accelerator and is the recipient of several major awards.

Mr. Blyth is president and founder of the nation-wide investment banking firm, Blyth and Company. Among a number of major services he has rendered in the civic and commercial areas are his services as a former governor of the American National Red Cross, Washington, and presently as a trustee of Stanford University and a director of Stanford Research Institute. He is also a director of several prominent business firms and of the San Francisco Chapter of the American National Red Cross.

Mr. Buttner has been closely identified with the growth of electronics since 1915. He has recently retired from the vice-presidency of research and development at International Telephone and Telegraph Corporation. He has served as managing director of International Marine Radio Company, vice-president of International Telephone Development Company during the period when that organization developed the ITT Instrument Landing System, associate director of International Telephone and Radio Laboratories, and president of Federal Telecommunication Laboratories during the period when the Navarho and Tacan radio navigation system developments were begun. Mr. Buttner has further served on a number of technical committees of national scope and is a Fellow of the I. R. E.

Mr. Pike will be known to readers for his work as an Assistant Secretary of Defense from 1953 to 1956 and for a time thereafter as Special Assistant to the President of the United States. He has as well been president or director of several prominent western firms and has been active in the civic area, serving as a director of the Los Angeles Chamber of Commerce and of several other major associations. He has served as western trustee of the Council of Profit Sharing Industries and is presently a trustee of Stanford University.

Dr. Terman is very well known to members of the electronics engineering profession for his books on electronics and radio engineering, for his service as president of the I. R. E. (1941) and for his wartime technical leadership. In addition, he is provost of Stanford University as well as dean of the School of Engineering. During the war he was director of the chief U. S. radar countermeasures laboratory, the Radio Research Laboratory at Harvard University. He is a member of numerous major scientific groups and governmental advisory committees and has received a number of awards for his work in these capacities.

Continuing Board members are -*hp*- President David Packard, Executive Vice-President William R. Hewlett, and Finance Vice-President W. F. Cavier.