LETTERS TO THE EDITOR

PHYSICS

Kallman's Bipolar Negative Resistor

KALLMAN has described a bipolar negative resistance element using a few grains[1,2] or thin layers[2] of semiconductor material. Later[2] he describes a technique using "plain iron wire". The purpose of this communication is to emphasize the elegant simplicity of the latter method; it is found possible to demonstrate many of his results in less than 1 h, using only readily available materials.

About 60 cm of 20 s.w.g. soft iron wire was cleaned with metal polish, and heated in air by a current transformer to just below red heat (judged in semi-darkness). After 25 min heating, the wire was removed, cut in half and connected to a 'Tektronix' type 575 transistor-curve tracer. The wires were arranged to cross and touch lightly.

After suitable adjustment of contact position and pressure, a curve (Fig. 1) was obtained. A rounded turnover at +4·8 V and 0·3 m.amp is indicated, followed by a negative resistance region up to 0·7 m.amp. A slope resistance of about −1·0 kΩ is obtained. Further adjustment produced Fig. 2, where the turnover is at about +5·5 V and 0·2 m.amp, followed by a negative resistance region up to 0·7 m.amp. A slope resistance of about −1·7 kΩ is indicated, together with a burst of oscillation presumably due to energy storage circuits within the curve tracer being maintained in self-oscillation at the most active part of the negative resistance characteristic. Both curves were taken with a 20 kΩ limiting resistance, the scales being 0·5 V/div. horizontally and 0·2 m.amp/div. vertically. The sweep voltage was a full-wave rectified 50 c/s sinewave.

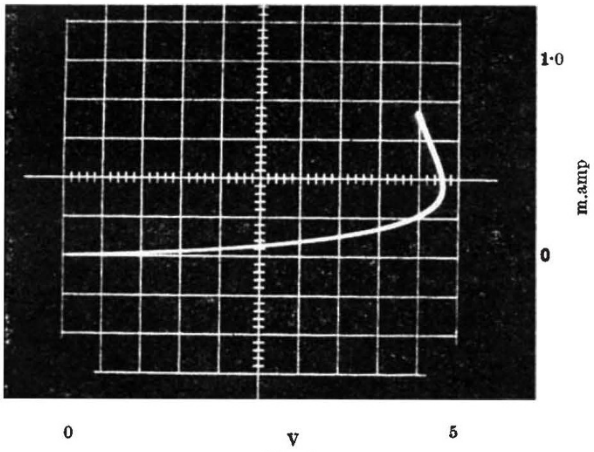

Fig. 1

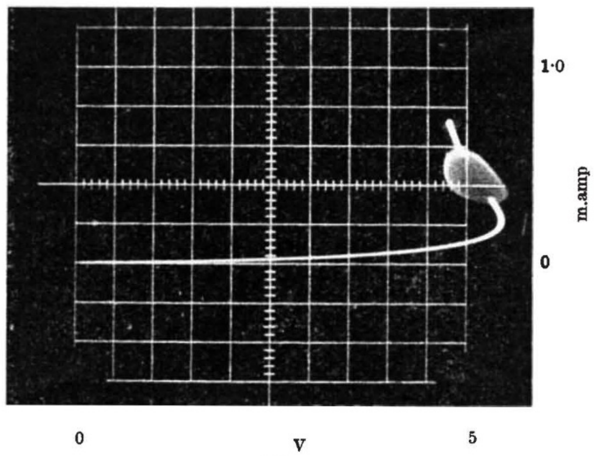

Fig. 2

It was observed that a negative slope region could sometimes be formed from an all-positive-slope characteristic by suitable adjustment of the sweep drive, and that the negative slope could usually be destroyed by an increase of drive. Kallman implies[2] that his characteristics were displayed with 1·2-kc/s sinewaves often gated to 60/sec 15 per cent duty factor so as to minimize heating.

With the simple arrangement described here the characteristics shown were not as easily or stably produced or reproduced as suggested by Kallman, but the use of thinner wire (Kallman used 0·010 in. diam.) and a simple jig for adjusting the contact point and pressure should give a great improvement.

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[1] Kallman, H. E., *Proc. I.R.E.*, **50**, 2138 (1962).
[2] Kallman, H. E., *Proc. I.E.E.E.*, **51**, No. 2, 396 (1963).

Ultrasonic Excitation of Nuclear Magnetic Resonance of the Copper-63 and Copper-65 Nuclei in a Single Crystal of Copper

THIS communication reports the observation of the ultrasonic excitation of nuclear magnetic resonance in a metal single crystal. Using the direct method of Bolef and Menes[1] it has been found possible to detect the additional attenuation of an ultrasonic wave due to the nuclear spin-level transitions for both copper-65 and copper-63 nuclei in a copper single crystal.

The specimen was in the form of a half centimetre copper cube of purity 99·999 per cent; the cubic faces being aligned along the [100], [010] and [001] directions. Because of its high electromechanical efficiency and good acoustic impedance match to copper, a barium-titanate ceramic (80 per cent $BaTiO_3$, 12 per cent $PbTiO_3$, and 8 per cent $CaTiO_3$) (refs. 2 and 3) transducer was used. This was in the form of a 0·47-cm disk, plated on one flat surface. The fundamental thickness resonance frequency of the transducer was 5·0 Mc/s and it was possible to detect mechanical resonances of the specimen over a bandwidth of 4 Mc/s (ref. 3).

The specimen was coupled into a Pound Knight Watkins marginal oscillator[4] using a double tuned transformer similar to that utilized by Bolef and Menes[1]. The magnetic field was provided by a Newport Instruments electromagnet which was swept by applying a sweep voltage to the control circuits.

The magnetic field was modulated at 250 c/s and synchronous detection was used.

The specimen was driven at a mechanical resonance frequency (ν) of 5·223 Mc/s and the magnetic field was swept through the field value where the Larmor precession frequency of the nucleus concerned was approximately $\frac{1}{2}\nu$, that is, the ultrasonic excitation of transitions with magnetic quantum number changes of $\Delta m = \pm 2$ were observed. The magnetic field was measured using a proton resonance magnetometer[5].