tween input and output but presents infinite impedance to one, zero impedance to the other.

3) A relaxation oscillator is formed by an assistor in parallel with a capacitor, fed via a resistance from a battery. The circuit is familiar with neon lamps but requires now only 10 v.

4) The symmetrical π section of resistances $+R_i$ and $-R_i$ seen in Fig. 1 is known[3] to transform any load Z_L into the input impedance $Z_i = -R_i^2/Z_L$, and so do the π section with the resistance polarities reversed and the two T sections formed from $+R_i$ and $-R_i$ Such transformation holds true not only for resistive loads but for reactances as well, transforming a load capacity C_L into a negative inductance $L_i = -R_i^2C_L$ and a load inductance L_L into a negative capacitance $C_i = -L_L/R_i^2$. The load shown in Fig. 1, a series-tuned circuit of positive L_L, C_L and R_L is transformed into a parallel-tuned circuit of negative inductance L_i, negative capacitance C_i and negative shunt resistance R_i, of the same resonance frequency. When tested[4] the circuit behaves much like a familiar resonance circuit, but if it is shunted by a real capacitance $+C_p$ the frequency does not as usual drop but rises, since $+C_p$ is to be subtracted from negative C_i, towards infinite frequency for $C_p = -C_i$ (but the circuit fails before that).

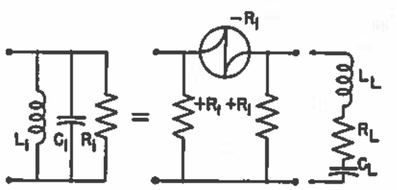

Fig. 1.—Negative-impedance inverting section; L_i, C_i, and R_i are negative.

5) A cascade of any two of these inverting sections, with $\pm R_1$ and $\pm R_2$, respectively, transforms any load Z_L into an input impedance $Z_i = Z_LR_1^2/R_2^2$, thus acts like an all-pass transformer of turns ratio R_1/R_2.

Applications of a bipolar negative resistance are barely explored; the use of square-waves in place of dc supply stands out.

6) In the sinewave oscillator mentioned before[1] the batter E_0 may be replaced by a squarewave generator of voltage $\pm E_0$ and of a frequency high compared with that of the sinewaves. Except during the brief transition times the assistor is then supplied with the same current as before and presents the same negative resistance to the oscillator circuit. But since supply polarity, hence curvature of the negative resistance region, keeps reversing during each sinewave excursion, this 50/50 time sharing push-pull use of a single assistor reduces nonlinearity and cancels all even harmonics like a conventional push-pull circuit. Note that droop or rippling of the squarewaves do not harm as long as they are the same for both polarities; they merely average over the negative resistance.

7) Amplifiers are based on near-cancellation of source and load resistances. For instance a squarewave-fed assistor in series with source and load makes a drift-free dc and ac push-pull amplifier for frequencies below that of the supply. All such stages of a cascade can be fed from the same supply; they could be continually monitored by means of the supply current without interfering with their use.

8) Bistable—memory—circuits can also be fed with squarewaves. The simplest circuit seems to be that of Fig. 2(a), (b); it assumes $T = R_sC_s$ comparable to a half cycle and a supply voltage $\pm E_0$ regulated to just safely below the peak voltage E_p. During a half cycle when the assistor is OFF, i_1, E_1, almost no charge will build up on C_s; the assistor cannot fire after supply-polarity reversal. But let (due to some trigger such as a voltage increase) the assistor be ON for a half cycle, i_2, E_2. Then the voltage drop i_2R_s will charge the capacitor C_s to nearly $E_0 - E_2$, opposing the supply voltage before, but aiding it immediately after, its reversal. Then for $E_0 - E_2 > E_p - E_0$ the assistor will fire again, re-charge the capacitor so that it will aid at the next reversal, and so stay ON.

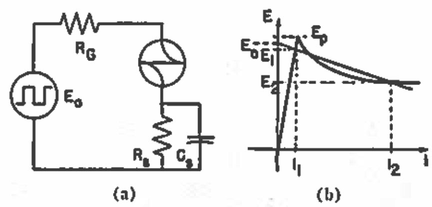

Fig. 2.—Squarewave-fed bistable circuit.

H. E. Kallmann
417 Riverside Drive
New York, N. Y.

[3] A. C. Bartlett, "Boucherot's constant-current networks and their relation to electric wave filters," *J. IEE (London)*, vol. 65, pp. 373–376; 1927.
Balth. van der Pol, "A new transformation in alternating current theory with application to the theory of audition," Proc. IRE, vol. 18, pp. 221–230; February, 1930.
L. C. Verman, "Negative circuit constant," Proc. IRE, vol. 19, pp. 676–681; April, 1931.

[4] The negative resistance used for this test was a three-transistor circuit derived from that of J. S. Schaffner, U. S. Patent 2,864,062.

On "The Engineer and the Life Sciences"*

In connection with Dr. Brown's fine article[1] on the status of biomedical engineering in the United States today, we would like to point out one misclassification.

The Case Institute of Technology, Cleveland, Ohio offers, at the present time, a sequence of courses leading to the M.S. and Ph.D. degrees in this field. Undergraduate courses are also available. At the present time, the biomedical engineering group at Case consists of four Professors, two Associate Professors, and one Assistant Professor, and a number of graduate research assistants.

Research is carried out in conjunction with Western Reserve University Medical School, Cleveland, Ohio and Highland View Hospital, Cleveland, Ohio. The Engineering Design Center and Systems Research Center at Case also cooperate in this program. For further information may we refer you to the 1962–1964 Catalog of Case Institute of Technology.

A. Clark
A. D. Waren
Case Inst. of Tech.
Eng. Div.
University Circle
Cleveland, Ohio

* Received September 10, 1962.

[1] J. H. U. Brown, Proc. IRE, vol. 50, pp. 1758–1762; August, 1962.

Causality?*

Can it be as Sid Deutsch believes,[1,2]
Or has A. Speiser shown the way?[3]
Should one put faith in causalities
Or should free will take its sway?

I well may ask, as did Golay,[4]
Questions to which no answers come.
As, what was there before today?[5]
Was there one point to which all must sum?[5]

Or, can we our beginning know?
Or, can we final basic laws obtain?[6]
The answer is intuitive and no!
Man, the poet shows, can not be so vain.

In science causalness is perforce
A kind of mortal definition,[7]
Which in history has run its course;[8]
A postulate now, at our volition.[9]

But, in worldy living so true,
If creativity be but illusion,[1]
Why is contemplation known but to few?
Why in men's minds is there sin?

Why, if Deutsch be right, must each of us,
If truly causal this universe be,
Make a nondestructive fuss[10,11]
When our minds for such thoughts are never free?

R. W. Newcomb
Dept. of Electrical Engineering
Stanford University
Stanford, Calif.

* Received October 31, 1962.

[1] S. Deutsch, "Causality," Proc. IRE (*Correspondence*), vol. 50, no. 2, p. 222; February, 1962.

[2] S. Deutsch, "Author's comment," Proc. IRE (*Correspondence*), vol. 50, no. 10, p. 2142; October, 1962.

[3] A. P. Speiser, "Causality," Proc. IRE (*Correspondence*), vol. 50, no. 10, pp. 2141–2142; October, 1962.

[4] M. J. Golay, "Reflections of a communication engineer," Proc. IRE, vol. 49, no. 9, pp. 1378–1382; September, 1962.

[5] *Ibid.*, p. 1379.

[6] *Ibid.*, p. 1381.

[7] D. Youla, L. Castriota and H. Carlin, "Bounded real scattering matrices and the foundations of linear passive network theory," IRE Trans. on Circuit Theory, vol. CT-6, no. 1, pp. 102–124, March, 1959, see p. 111.

[8] M. Bunge, "Causality, chance, and law," *American Scientist*, vol. 49, no. 4, pp. 432–448; December, 1961.

[9] R. W. Newcomb, "On causality, passivity and single-valuedness," IRE Trans. on Circuit Theory (*Correspondence*), vol. CT-9, no. 1, pp. 87–88; March, 1962, see above Fig. 2.

[10] S. Deutsch, "Causality, consciousness and creativity," *Cybernetica*, vol. 4, no. 3, pp. 154–170; 1961, see p. 170.

[11] S. Deutsch, *Sci. Am.*, Letters, vol. 205, no. 6, p. 14; December, 1961.