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Magnetostriction Oscillators

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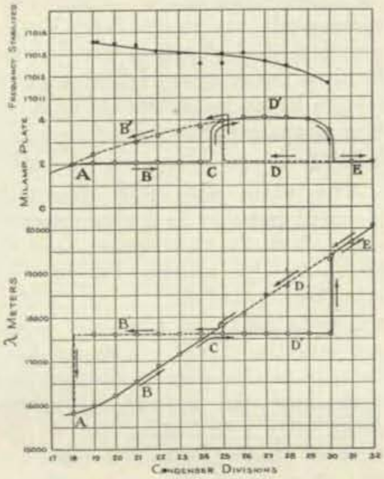
PART II

In the June issue of the "Experimenter" we described the phenomenon of magnetostriction and its application to frequency standardization as discovered by Professor G. W. Pierce of Harvard University. We propose at this time to discuss other interesting features of this work.

The reader will recall that use was made of a rod of invar, nichrome, or other suitable metal possessing magnetostrictive properties, which was surrounded by two coils located respectively in the grid and plate circuits of a Hartley vacuum tube oscillator, but with the coupling, however, in the reverse of the customary sense. When such a circuit is resonated by a suitable capacity to the natural longitudinal period of the rod the frequency of the electric oscillations will become accurately stabilized for an appreciable interval above and below the resonant point on the tuning condenser.

This standardization is aptly shown in the diagram wherein the horizontal scale (abscissae) indicates arbitrary readings on the variable condenser dial, the resonant point being at 24.5. Consider first the lower portion of the figure. If the rod is held so that it cannot vibrate and the condenser is gradually increased, the frequency will decrease or the wavelength will increase as shown, in the normal manner, along the curve ABCDE. If, however, the rod is left free to vibrate, the wavelength will vary with increasing capacity along the path ABCD'E.



That is, the wavelength or frequency will remain stabilized at a constant value from 24.5 to 30 divisions on the dial and will then jump immediately to the unstabilized value at E.

Similarly, if the condenser capacity is decreased gradually with the rod held so that it cannot vibrate, the wavelength will retrace the path EDCBA; while, if the rod is free to vibrate, the variation in wavelength with decreasing capacity will follow the path EDCB'A, being stabilized at the natural frequency of the rod from 24.5 down to 18 divisions on the condenser dial, whence the control suddenly breaks and the wavelength drops abruptly to the unstabilized value at A.

The variations in plate current corresponding to these four operations are shown in the central portion of the figure. It will be noted that for the unstabilized circuit this current remains constant at two milliamperes, while, with the rod free, the plate current jumps rapidly to about four milliamperes as the stabilizing action is brought into play.

The writer is indebted for the above, and considerable other data in these articles, to a paper by Professor Pierce published in the Proceedings of the American Academy of Arts and Sciences, Volume 63,—April, 1928.

The independence of the rod-stabilized frequency of the vacuum tube constants is more pronounced than in the case of the piezo crystal-controlled oscillator. For instance, doubling the plate voltage affects the former by about one part in 30,000 and the latter about six to eight parts in 30,000.

The accuracy with which the rods may be calibrated merely by cutting them to the proper length, as determined by the equation:

$$V = 2\ LF$$

where F is frequency in cycles per second, L the length of the rod, and V the velocity of sound in the rod expressed in corresponding units, is illustrated by the following data. A series of 21 stoic metal rods, 0.79 centimeters in diameter and calibrated in steps of one kilocycle from 10 to 30 kilocycles, were accurately measured for frequency and length at 20 degrees centigrade. The product of the length in meters multiplied by the frequency varied between extreme limits of 2077.5 and

2081.7, the average value being 2079.6, which is, of course, one-half the velocity of sound in meters per second in the rod. Using a similar set of 32 nichrome rods, 0.96 centimeters in diameter, and calibrated in one kilocycle steps from 26 to 57 kilocycles at 23 degrees centigrade, this product varied between extreme limits 2480.3 and 2496.5, average value 2490.3. It is interesting to note that if a rod is cut or ground slightly too short in calibrating the frequency may be lowered by grinding to reduce the girth of the rod.

In considering the use of magnetostriction rods as accurate frequency standards the question of temperatture coefficient of frequency is vital. The following table gives this coefficient for certain magnetostrictive materials:

Material	Temperature Coefficient of Frequency
Nichrome	— .000107
Monel Metal	— .000151
Stoic Metal	.000224
Pure Iron	— .000171
20% Nickel, 80% Iron	— .000159
30% Nickel, 70% Iron	.000135
40% Nickel, 60% Iron	.000218
50% Nickel, 50% Iron	— .000064
60% Nickel, 40% Iron	Non-Oscillatory
70% Nickel, 30% Iron	Non-Oscillatory
80% Nickel, 20% Iron	— .000124
Pure Nickel	— .000132

This table shows, for instance, the frequency of a nichrome rod drops about .011 per cent per degree centigrade temperature rise, while that of a stoic metal rod, on the other hand, increases some .022 per cent per degree centigrade temperature rise. The figures given in the above table are relatively large compared with the temperature coefficients of piezo-controlled oscillators, which may be taken as of the order of .002 per cent per degree centigrade. By the use of proper alloys or properly designed bi-metallic rods, it is possible, however, to obtain magnetostrictive standards with a very low or vanishing temperature coefficient. Researches along these lines are at present under way and will be reported at a later date.

In the paper mentioned above Professor Pierce gives considerable interesting data regarding the use of magnetostriction rods as absolute frequency standards and their wide application in the calibration of secondary standards.

For general laboratory use the General Radio Company has designed the Type 389 Pierce Magnetostriction Oscillator. This instrument includes the elements of the rod-controlled oscillating circuit together with a stage of amplification containing a "speaker-filter" in the output. By means of a suitable control switch this filter may be inserted or removed according to whether or not a d.c. polarizing voltage is desired at the output terminals. Space is provided in the cabinet for dry cell plate and bias batteries, the six-volt filament battery being external. A rheostat and voltmeter control the filament voltage, while a sensitive milliammeter in the plate circuit of the oscillating tube, which is provided with an adjustable shunt, affords facilities for close observation of the plate current.

Provision is made for increasing the range of the variable air condenser several fold by the use of mica condenser units and a suitable control switch. A magnetizing key is also furnished whereby the rods may be given the necessary initial magnetization by an instantaneous application of current drawn from the plate battery.

The plate and grid coils are mounted together as a single removable unit on the top cover of the cabinet. In this manner the pair of coils best suited for the particular rod to be used may readily be plugged into the circuit. The coil unit contains a clamping mechanism for supporting the rod at its center point. By substituting one of the General Radio Type 384 coils for the Magnetostriction coil assembly a variable electric oscillator of the familiar Hartley type is obtained.

The high-mu Radiotron UX 240 or Cunningham CX 340 is recommended as the oscillator and the Radiotron UX 112-A or Cunningham CX 312-A tube as the amplifier.

The Type 389 Oscillator is contained in a walnut cabinet 12¾″ long by 8″ high by 12¾″ deep and weighs approximately 18 pounds.

As a convenient instrument for the calibration of secondary standards and other purposes the Type 489 Pierce Twin Magnetostriction Oscillator has been developed. This contains two complete Type 389 Oscillators and amplifiers built into a single convenient and portable instrument with provision for using common self-contained B and C batteries. Separate filament switches and rheostats enable either one or both oscillators to be used at will. A single filament switch for checking the filament voltage of one or the other system is used. Provision is made for varying the electro-static coupling between the two oscillators.

One of these twin oscillators may, if desired, be stabilized by a rod while the other takes the form of a variable Hartley oscillator (using the General Radio Type 384 coils). In this manner an extensive series of beat notes having definite harmonic relationships to the fixed fundamental frequency of the rod is made available for use in calibrating a wavemeter or in similar work, or, if desired, both oscillators may be rod controlled and definite fixed beats between them obtained.

The Type 489 Oscillator is mounted in a cabinet 19½″ long, 8″ high and 11½″ deep, and weighs approximately 30 pounds.

Both of these instruments are licensed for manufacture under patents pending of Professor Pierce and under Patent No. 1,113,149 for experimental use only.

Nichrome rods having natural frequencies at any values between 5 and 50 kilocycles are readily supplied. These are nominally supplied cut approximately to the desired frequency with the exact frequency measured to a precision of 0.1 percent.

Special rods above or below these limits may be made to order, also highly accurate composite rods of low temperature coefficient.

The following are net prices on this equipment. The 389 and 489 instruments are furnished less tubes, batteries, coil units, and rods.

Type 389 Pierce Magnetostriction Oscillator	$195.00
Type 489 Pierce Twin Magnetostriction Oscillator	$275.00
Nichrome rods within range 10,000 to 50,000 cycles cut approximately to specified length and measured to 0.1%	$25.00
Rods cut to 0.1% of required frequency	$40.00
Magnetostriction Coil Assembly	$30.00
Type 384 Coils for Variable Hartley Oscillator	$3.00 to $8.50

Prices of special rods on application.

Type 330 Filter Sections

Electrical filters are used extensively in studying the characteristics of communication equipment and in the transmission of electrical impulses of multiple frequency as exemplified by speech or music. Such filters consist of capacitance and inductance networks so designed that they allow certain frequencies to pass readily through them while at the same time they attenuate other frequencies strongly. By the use of filters, for instance, a composite sound may be divided into several parts or a fault in telephone apparatus may be remedied by attenuating or placing emphasis on certain ranges of the frequency spectrum.

Filters may be divided into four general classes as follows:

(1) Low pass filters which cut off all frequencies above a definite predetermined value.

(2) High pass filters which cut off all frequencies below a predetermined value.

(3) Band elimination filters which cut out all frequencies between two predetermined values.

(4) Band pass filters which cut out all frequencies below the lower and above the upper of two predetermined values.

These four classes of filters can be formed in a variety of networks, some simple and others more complicated in their structure. For a theoretical discussion of such filter networks the reader is referred to two texts; namely, "Transmission Circuits for Telephone Communication" by K. S. Johnson, and "Electric Waves and Oscillations" by G. W. Pierce.

An electrical filter may consist of a single network or section, or it may be rendered more effective by containing several recurrent sections joined in series.

If the variation in freqency is plotted horizontally, usually upon a logarithmic scale, while the corresponding attenuation of the high or low pass filter is plotted vertically (uniform scale) the so-called transmission surve of the device is obtained. This curve will have a steeper slope in the region of the cut-off frequency as the number of recurrent sections is increased. As a general rule, however, it is not worth while to use more than three similar recurrent sections. It is interesting to note that a multisection filter will have a number of humps in its transmission curve equal to the number of sections used. These humps can usually be detected only by careful measurements and are accordingly of minor consequence.

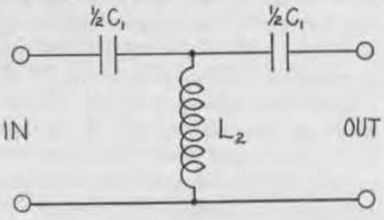


FIG. 1

T-SECTION H.P. FILTER

As an aid to the experimenter who desires to study the characteristics of such filters or to use them in communication circuits, the General Radio Company has developed a series of simple high pass and low pass filter sections mounted in individual cases. The high pass filters take the form shown in Fig. 1, which is known as a T type section; while the low pass filters are constracted in the form of a Π section shown in the Fig. 2.

Type Number	Form	Iterative Impedance	Cut-Off Frequency
330-A	Low Pass	600 ohms	500 cycles
330-B	High Pass	600 ohms	500 cycles
330-C	Low Pass	6000 ohms	500 cycles
330-D	High Pass	6000 ohms	500 cycles
330-F	Low Pass	600 ohms	1000 cycles
330-F	High Pass	600 ohms	1000 cycles
330-G	Low Pass	6000 ohms	1000 cycles
330-H	High Pass	6000 ohms	1000 cycles
330-J	Low Pass	600 ohms	2000 cycles
330-K	High Pass	600 ohms	2000 cycles
330-L	Low Pass	6000 ohms	2000 cycles
330-M	High Pass	6000 ohms	2000 cycles

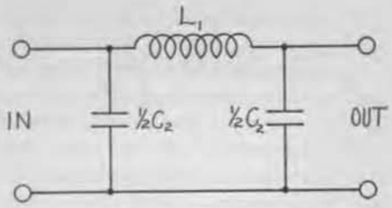


FIG. 2

Π-SECTION L.P. FILTER

In order to determine the electrical constants of the elements of such a filter it is necessary to know two things. First, the desired cut-off frequency, F, and second, what is known as the iterative impedance, Z, of the circuit in which the filter is to be placed. The values of capacitance and inductance for the high pass filter section may then be computed from the equations:

$$C_1 = \frac{0.07958}{FZ} \text{ Farads}$$

$$L_2 = \frac{0.07985Z}{F} \text{ Henrys}$$

where F is in cycles per second, and Z in ohms.

For the low pass filter we have in a similar manner:

$$C_2 = \frac{0.3183}{FZ} \text{ Farads}$$

$$L_1 = \frac{0.3183Z}{F} \text{ Henrys}$$

Below is given a list of high and low pass sections having impedances standardized at 600 or 6000 ohms and cut off frequencies specified as 500, 1000 or 2000 cycles. These individual sections are built into shielded metallic cans and comprise a suitably designed laminated-core inductance unit together with two calibrated wax paper condensers. They are provided with two input and two output terminal posts which, as shown in the illustration, have the so-called "bottle-top" clamp screws that permit the use of the convenient General Radio Type 274 plugs in connecting the section into any circuit.

The types listed, which carry a net price of $12.00 each, represent arbitrarily chosen values of impedance and cut-off frequency which find more or less extensive use in practice. The General Radio Company specializes in equipment of this sort and similar sections having any desired electrical constants may be obtained on special order at a slight increase in price.

Silcon vs Nickel in Transformer Design

Developments in loudspeakers made in recent months have resulted in instruments which have extended the reproducable range of frequency by some seventy-five to one hundred cycles downward. At the same time there has been a downward extension of the frequency range transmitted by broadcast stations. These factors have combined to revise the requirements for satisfactory performance of audio transformers. A year ago, there was little justification for audio transformers reproducing frequencies much below one hundred cycles, since none of the speakers then available were capable of producing an audible sound at such frequencies, even though it was present in the broadcast transmission which it was not.

As a result of these developments, the low frequency cut-off of audio transformers has been moved steadily until transformers are demanded which will amplify sixty, or even thirty cycles.

The design of such transformers has not involved any new principles, but rather the overcoming of practical difficulties involved in the adaptation of well-known principles. The problem of raising of the lower end transformer characteristic is primarily one of increasing the input inductance of the transformer although the lowering of the plate impedance of tubes has had the effect of improving the characteristics of transformers of earlier designs. The inductance of the transformer depends upon three factors, the number of turns of wire on the coil, the size of the core, and the permeability of the core material. The gain in inductance which may be had by adding primary turns is limited by the fact that the secondary turns must also be increased unless the turns ratio is lowered. The result is the loss of high frequencies as a result of coil capacity.

The high permeability nickel alloys are being used to an increasing extent for audio transformers. These alloys of nickel and iron have the property of high permeability at low flux densities, the conditions encountered in audio transformer primaries.

These alloys have however some disadvantages. The high permeability is maintained over a rather limited range of flux density, and falls off rapidly at higher or lower values. Simply stated, such cores saturate easily. This difficulty is becoming more important as the plate currents of vacuum tubes are increased. A more serious objection yet is that the transformer is permanently damaged by an increase in field strength such as might result from accidental connection in a circuit without a "C." battery, or where a "C." battery was run down or where the plate current was abnormally large for any other reason. Such temporary increase in flux through the core permanently changes the characteristics of the material. Silicon steel on the other hand is not permanently affected by increases in flux. The frequency characteristic of the transformer is of course affected by core saturation while it exists, but the effect is not lasting. These considerations render the nickel alloy transformers particularly valuable for special laboratory work, or in commercial installations where care is taken to insure proper operating conditions. The ruggedness of the silicon core type of transformer however recommend it for general experimental use where conditions are frequently hard upon delicate apparatus. All the electrical advantages of the nickel alloys may be obtained with silicon steel by adjustment of other factors in the design.

It was found that when the lower end of the characteristic had been extended as desired, by changes in the coil and core, there was a tentendency to resonance at high frequencies as well as a falling off of amplification. These difficulties were overcome by changes in coil design. The resonance effects at high frequency are due to leakage reactance, i. e. flux not linking both primary and secondary coils, and by coil capacity. The loss of amplification at high frequencies is due to internal coil capacity, principally in the secondary. It was found possible to reduce both these effects by a form of coil construction which sandwiches the primary between two sections of the secondary. This type of winding not only reduces leakage reactance by increasing the coupling between primary and secondary, but also reduces the internal capacity of the secondary by breaking it up into two sections.

In the Type 585 Transformers silicon steel has been used as a core material. The coils are of the sandwich type described above. The result of this construction is a transformer possessing a practically flat frequency characteristic from 30 to 6000 cycles.

Bargains!

From time to time we have items that have accumulated from overstock, design changes, or similar reasons, which we prefer to move at sacrifice prices in order that our regular stock may be kept fresh. Such items will be listed in this column whenever they occur. All offerings are, of course, subject to prior sale. *In ordering, be sure to refer to special sale price.*

4000 Type 214-A 20-ohm Rheostats

Standard Design.	Overstock.
Quantity	Unit Price
10	$1.25
50	1.00
500	.65

3500 Type 301 10-ohm Rheostats
Manufacturers' type without knob

Quantity	Unit Price
10	$ .50
50	.35
500	.25

1000 Type 301 6-ohm Rheostats

Standard Design.	Overstock.
Quantity	Unit Price
10	$ .70
50	.55
500	.40

2000 Type 301 12-ohm Rheostats

Standard Design.	Overstock.
Quantity	Unit Price
10	$ .70
50	.55
500	.40

Because of the general availability of condensers, we shall no longer list our Type 236 Low Power Factor Paper Condensers. These condensers are rated to stand continuously 300 volts D.C. and are tested at 500 volts D.C. They are mounted in metal cans 1″ x 1″ x 4″. These condensers are particularly useful for radio frequency by-pass work, where low resistance is of importance The following quantities are available, subject to prior sale.

225	0.1	Microfarad capacity
200	0.2	Microfarad capacity
25	0.25	Microfarad capacity
875	0.3	Microfarad capacity
375	0.4	Microfarad capacity
225	0.5	Microfarad capacity

Quantity (assorted)	Unit Price
5	$ .40
10	.35
50	.25
100	.20

Regular price $1.00 net.